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A Comparison of Boolean-based Retrieval to the WAIS System for Retrieval of Aeronautical Information: Final Report

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Abstract

An evaluation of an information retrieval system using a Boolean-based retrieval engine and inverted file architecture and WAIS, which uses a vector-based engine, was conducted. Four research questions in aeronautical engineering were used to retrieve sets of citations from the NASA Aerospace Database which was mounted on a WAIS server and available through Dialog File 108 which served as the Boolean-based system (BBS). High recall and high precision searches were done in the BBS and terse and verbose queries were used in the WAIS condition. Precision values for the WAIS searches were consistently above the precision values for high recall BBS searches and consistently below the precision values for high precision BBS searches. Terse WAIS queries gave somewhat better precision performance than verbose WAIS queries. In every case, a small number of relevant documents retrieved by one system were not retrieved by the other, indicating the incomplete nature of the results from either retrieval system. Relevant documents in the WAIS searches were found to be randomly distributed in the retrieved sets rather than distributed by ranks. Advantages and limitations of both types of systems are discussed.

1. Introduction

Information retrieval has become an important issue in business and government due to the development of high-speed networking and finding aids such as Gopher, World-Wide-Web, Mosaic, and WAIS (see Obraczka, Danzig, & Li, 1993 for an overview of different systems). Such systems have provided broad ranges of computer users generally easy access to Internet resources, but access is not sufficient to assure information-seeking success. There is no evidence on how such systems perform either quantitatively or qualitatively and no guidance on what information seeking strategies are appropriate. Although the information retrieval (IR) community agrees that networked resources are important research and development domains, there have been no systematic studies of retrieval performance in networked environments. Practice rather than theory is driving development. This situation is problematic since networked end-user environments have enormous implications for IR researchers and information specialists. To explore how one such system performs, a comparative investigation was conducted for the WAIS system and a Boolean-based retrieval system. This report presents results from this study and makes suggestions for developers, evaluators, and users.

1.1. Boolean-based Systems

The development of systems to store and retrieve bibliographic records has been dominated for the past 30 years by the model that uses a Boolean-based retrieval engine and inverted file architecture to match query terms to document terms (these will be referred to as Boolean-based systems (BBS)). A search for relevant records is conducted in one of two modes: (1) using designated descriptors, typically including assigned index terms, authors names, and dates of publication; (2) using the free-text capability, which searches for individual words and phrases within citations. Among the prominent examples of such systems are Dialog, BRS, Medlars, and NASA RECON.

These systems support the bulk of IR practice because there is a large installed base of databases and a community of professional intermediaries who have learned to maximize their value. Over the years these systems have added new features and tools so that professional intermediaries can have even better control in mapping user needs to system capabilities. Today's BBSs allow skilled searchers to tightly control the scope and format of results (e.g., high recall or high precision; specific fields or full records), and new features such as Dialog's Target (Dialog, 1993) offer new search capabilities based on frequency of word occurrence as well as traditional exact match retrieval. The specialized features make these systems powerful but require that users be highly trained to use their rich command languages.

To attract end users, BBS vendors offer alternative systems that feature menu-driven interfaces, online thesauri, online help and abbreviated command sets (e.g., Knowledge Index, BRS AfterDark, Grateful Med). Thus, BBSs continue to evolve from the rigid, exact-match systems often criticized in the research literature to diverse collections of interfaces that aim to serve professional and novice searchers.

Although these systems continue to evolve, BBSs are often criticized in four regards (e.g., Larson, 1992): 1) users must use Boolean logic to formulate queries; 2) Boolean operators are either too coarse (OR is too inclusive) or too fine (AND is too restrictive); 3) query terms are treated equally regardless of their relative importance to the user's information need; and 4) all retrieved documents are treated as equally relevant (documents are not ranked).

1.2. Frequency of Occurrence-based Systems

An alternative approach to information retrieval uses a vector space model for documents and queries (Salton & McGill, 1983). The basic idea behind the vector model is to represent every document as an N-dimensional vector where N represents the number of words in the index language (this can be a small set of controlled terms or, in the extreme case, every word in the document collection) and each cell contains a value related to frequency of occurrence of that cell's index word in the document. Thus, a document that does contain the word "thermal" but does not contain the word "radiation" would be represented by a vector that contains a 0 in the cell for the index word "radiation" and some non-zero value, dependent on the weighting scheme used, in the cell for the index word "thermal." Queries are likewise represented as N-dimensional vectors, and each document vector is compared to the query vector according to a similarity metric (e.g., the dot product or the cosine of angle between the vectors).

Although computationally intensive, this type of representation allows all documents in the collection to be ranked in similarity to the query, thus mitigating the exact match limitations of Boolean-based approaches. Research related to this approach to information retrieval considers parameters such as types of term weighting schemes, types of similarity measures, size and composition of the indexing language (e.g., highly controlled or all words in the database), treatment of word phrases and proximity limits, and types of stemming.

In addition to the SMART studies conducted by Salton and his colleagues, Harman and her colleagues have demonstrated the usefulness of the vector approach (Harman & Candelea, 1990). Harman, McCoy, Toenese & Candelea (1991) argue that the frequency of a term's occurrence within the document taken in relation to its frequency of occurrence across the entire record file and in relation to the length of the document provides an accurate indication of the importance of the term in the documents and query. In this way, the system numerically determines that the term "AIDS" has great meaning for occurrences within a psychological counseling database, while being relatively unimportant within an AIDS database. Of course, this example also illustrates one of the dangers of both word matching and word counting approaches to full-text databases--homonyms can lead to irrelevant documents being retrieved in the BBS case and to misranked documents in the vector case.

Based upon the term weighting values and the relationships that document terms share with users' query terms, vector-based systems ordinarily rank retrieved record sets in order of descending similarity to the query. The first citation presented to the user is the one with the highest similarity score. In theory, the system retrieves the entire set of documents that have any of the query terms (equivalent to a OR of all free-text terms in a BBS) ranked according

to their similarity to the query. In practice, cutoff values are used to return only the top-ranked documents.

Another information retrieval technique is known as relevance feedback (Ide, 1971; Rocchio, 1971). This approach displays document citations to users and invites them to inform the system which citations are relevant. The relevant citations are then used to locate similar documents. Each iteration of the search is an opportunity to further refine the search by allowing the system to readjust the query vector by including and/or discarding selected terms. The user can proceed with as many iterations as necessary to retrieve those documents which best meet the perceived information need. Although either the Baleen or vector techniques may be used with relevance feedback, it is most often associated with the vector approach since term weights can be adjusted in the query¹.

The present study evaluated and compared the performance of a traditional system used for aeronautical engineering databases and a system based on vector retrieval and relevance feedback. Since these two systems take advantage of such divergent technical processes, representations of user queries, and methods for displaying documents, the selection of evaluation measures and the attributes used for comparison were carefully chosen and applied to capture the strengths and weakness of both types of systems.

1.3. NASA/RECON

NASA's implementation of RECON is one of the oldest of the large online bibliographic retrieval systems. In operation since 1969, it holds the special status of being the government's first large online retrieval system. A BBS, the system offers a wide range of commands for formulating queries and specifying the format of output. The system provides access to a body of citations to the scientific and technical literature for its users, who are primarily aerospace researchers and information specialists within the U.S. Government. In 1993, the database held about 3,000,000 citations organized within 29 files, which are grouped into 17 clusters. The largest of these are Scientific and Technical Aerospace Reports (STAR) and International Aerospace Abstracts (IAA).

1.4. Wide Area Information Server (WAIS)

WAIS is the name of a suite of programs using the client/server architecture and based on the NISO Z39.50 information retrieval protocol (Kahle & Medlar, 1991). This protocol allows searchers using a variety of interface "clients" to formulate queries which are translated into appropriate formats for particular "servers" that contain the bibliographic or primary information. A WAIS client allows users to formulate queries in "natural language" (terms or phrases can be typed in or cut and pasted from other sources in some clients) and to select as

¹ This automatic refinement technique is similar to the traditional manual citation pearl growing technique used in online searching wherein the user studies the characteristics of those valued retrieved documents ("pearls") and then attempts to retrieve more citations like them by adding the appropriate index terms to the query statement.

many databases (servers) as they wish for concurrent searching. A WAIS server is a retrieval engine that uses statistical ranking algorithms to return lists of information objects (typically documents, but possibly images, program code, etc.) that are ranked according to weighted frequency of occurrence. WAIS clients also invite users to provide relevance feedback to the servers by selecting relevant documents, phrases, or sections from the retrieved objects. Terms from these objects are fed back to the server and new ranked lists are sent to the client. A variety of public domain clients are available for different platforms (e.g., MS-DOS, Macintosh, X-windows), and there are public domain as well as commercial servers. Thus, WAIS searching requires high-speed connectivity to be effective and allows users to search a variety of servers without specialized training in query languages. Many WAIS servers are available through the Internet, and the client and server software packages are undergoing continued modification.

The proponents of WAIS system architecture make the following arguments: 1) The information search is driven by user perceptions of relevancy instead of the system's definition translated as an exact match between index and query terms. This distinction has been cast as the tension between relevancy, a match of document to query term, and pertinence, a match of document to actual information need. 2) The query representation automatically incorporates changes in the user's relevance judgments into the query vector and the order of the retrieved sets as the search proceeds. 3) The search process is made relatively transparent, allowing the user to concentrate fully on the intellectual demands of the information task instead of manual query refinement required by traditional systems. 4) Browsing by the user in the retrieved document sets can improve the final set's quality in terms of precision and recall and make it more reflective of the user's changing perception of the information need. Bates argues that this technique of systematic iterative retrieval, or "berrypicking," reflects how users actually approach the retrieval task and increases user understanding of their information need (Bates, 1989). 5) Searching different databases simultaneously insures a radical expansion of the retrieval engine's power and, probably, of the subsequent end value of the delivered document set (e.g., Stanfill & Kahle, 1986).

1.5. Study Perspective and Research Questions

As these brief descriptions imply, there are profound differences between BBS and WAIS in both surface and deep structure. Keen (1992) said, "Comparisons between Boolean and non-Boolean are not commonly attempted, and encounter difficulties with finding a control variable fair to both systems." Additionally, there are no accepted metrics for assessing the effectiveness of interactivity, an especially key aspect of WAIS. The approach that was taken for this work was to explore the differences between the two systems by controlling the database and search questions to ascertain strengths and differences for both approaches.

There is no overarching agreement within the information science field on the most appropriate measures to invoke and methods to use in evaluating an information retrieval system. Two measures that have been central to the debate about evaluation are recall and precision. Recall is the ability of the system to present all relevant items and is defined as the ratio of relevant documents retrieved to the number of relevant documents in the database.

Precision is the ability of the system to present only relevant items and is defined as the ratio of relevant documents retrieved to the total number of documents retrieved. It is generally recognized that recall and precision are inversely related and, thus, comparisons must be made at different levels of each.

The typical criticism of recall and precision as performance metrics relates to the problems of relevance (McCarn & Lewis, 1991). For example, 1) How does one determine the relevant items from those contained within a large information storage and retrieval system? 2) How can one be sure that users really care about relevant items not retrieved? 3) By what criteria should relevance be determined and to what degree are these judgements reliable? Beyond the individual interpretations of what is relevant to a question, even order effects have been found to influence judgments (Eisenberg & Barry, 1988). Nonetheless, recall and precision have become standard metrics for IR studies and were the first point of comparison for the work summarized here. Recall is the most troublesome value to compute in practice since it requires knowledge of the number of relevant documents in the entire database. Since this is impractical in working environments, this value is derived from extrapolation or estimates. For a system like WAIS that ranks documents and has quite severe cutoff levels (50 documents in the client used for these studies), recall is particularly problematic since not only must extrapolations be used to determine the number of relevant documents in the database, but adjustments for the cutoff limits must be invented. Additionally, recall has been questioned as a usable metric for large databases since there seems to be little overlap in relevant citations retrieved by different queries (Belkin, Cool, Croft, & Callan, 1993). Given these problems, recall was not used as a dependent measure in this study. The raw number of relevant documents is used for gross comparisons, and precision values are used for systematic comparisons.

Other criteria have been offered for IR evaluation. For example, Cleverdon (1964) not only used recall and precision but discussed effort (defined as the effort required by users to conduct the search), time (defined as the time necessary to generate the complete set of retrieved items), presentation, and coverage. Other possible criteria include cost, system learnability, system usability, and searcher satisfaction. Since the focus of this study was on retrieval performance, these criteria were not systematically assessed.

Two main questions guided this study and spawned more specific questions as data collection took place. These questions were:

- How do WAIS and the BBS perform when high recall, or the retrieval of all relevant documents, is the goal of a search?
- How do WAIS and the BBS perform when precision, or the retrieval of only relevant documents, is the goal of a search?

The end goal of the study was not to "prove" which is the "better" system. Rather, it was to provide a context wherein each system could display the features and capabilities which distinguish it from its counterpart. To this end, comparisons were used as the basis for

discussions of the two different systems and as a springboard for gaining a better understanding of the particular values and limitations of both Boolean- and vector-based methods of information retrieval.

2. Methodology

2.1 Database and Search Systems

The database which served as the raw material for the two retrieval engines consisted of records in the Aerospace Database dated within the three year period 1990-1992. The Aerospace Database contains records for publicly available documents from NASA's STI Database. This set of documents consisted of approximately 205,000 document records which contained about 32 million words, about 540,000 of which were unique.

This database was mounted on a WAIS server (commercial version 1.0.10) on a Sun workstation at NASA's STI Program Office. The database used for the work reported here was not stemmed, so all results are based on exact matches of words in queries, a possible disadvantage from a recall perspective². The WAIS database was accessed over the Internet via an ethernet connection using a public domain Macintosh WAIS client (version 1.1). This client offered a maximum cutoff value of 50 documents, but consistently returned a maximum of 45 documents.

As an example of a BBS, the Aerospace Database was accessed via the DIALOG network (Dialog File 108) using a MS-DOS platform and 2400 baud modem. All searches were date-limited to the same three year period as the records contained in the WAIS server.

2.2. Search Questions

Volunteers from among graduate students in aeronautical engineering were solicited to participate in the study. Their role was to supply questions (one question from each participant) for search and to decide upon the relevance of retrieved citations. Four students volunteered. Each was at a different stage in his research project; their questions varied in subject, complexity, and specificity. Two reference interviews were held with each participant. Prior to the first interview, the students sent an initial statement of their questions to the research team. These questions are summarized in Figure 1. During the first interview, they were asked to state their questions again and to note any synonyms or related terms. They were also asked about the usefulness of sources already consulted.

2.3. Procedure

The first step in the search process was to retrieve as complete a set of relevant documents as possible from the database. This was done by conducting exhaustive high recall searches on the Aerospace Database accessed through the Dialog system. Search terms were taken from the participants' queries, the print version of the NASA Thesaurus (1988 edition with

² However, Harman (1991) has demonstrated that stemming offers few advantages when ranking algorithms are used.

updates), and the online thesaurus in Dialog, which supplied the newest indexing terms. Free text searching was used as needed. For each of the four questions, a search strategy that would maximize recall was developed. Experienced online searchers from outside the project reviewed the strategies and offered suggestions for improvement.

Two searches in the Aerospace Database accessed through Dialog were conducted for each question. The first search was exploratory, incorporating terms in the original query statements and from the NASA Thesaurus. The second search expanded the terms used to include as many applicable terms as possible. In one case (question 3), a set of about 2500 citations was limited by NOTing out the common phrase "computational fluid dynamics" so that the set provided to the requestor was more manageable. These searches are referred to as the BBS recall searches. See Appendix A for search strategies.

Figure 1. Original Search Questions

Subject 1. The forces of pressure used to predict what the effect would be on a wing using computer models.

Subject 2. Basic Objective: Design of Flight Control System for Flexible Aircraft using Modern Control Theory.

Some Necessary Keywords (or Key Sentences) are Application of H-Infinity & H-2 Control Theory to Flight Control System; Development of Flexible Aircraft; Dynamic Model for Flight Control Design; Modern Control Theory & Its Implication to Aircraft Flying/Handling Qualities; Application of Active Control Technology to Transport Aircraft; Stability and Control of Control Configured Vehicle.

Subject 3. Adaptive gridding on structured grids. Other keys words I am interested in are "redistribution" and "truncation error." Some key words which are not of interest are "unstructured grids" and "refinement."

Subject 4. Computational Fluid Dynamics. I am trying to model flow over a bluff body, (something like the automobile side view mirror). I am using a computer code which solves the equations governing fluid dynamics. This branch of study to simulate flow using computers is called Computational Fluid Dynamics as opposed to conventional wind tunnel testing. I usually look for following Key Words: Unsteady, Incompressible, Bluff Body flows; High Reynolds number Flows, Turbulence Modelling; Finite Analytic Method; Non-Stationary turbulence; Ground effect; Unsteady pressure in incompressible flow.

A member of the research team met with each of the subjects to present the retrieved citation set. The team member asked the participant to rank the relevance of each citation, using a

five-point scale with 1 as "Not Relevant" and 5 as "Highly Relevant." The citations rated 4 "Relevant" and 5 "Highly Relevant" formed the first component of the set of relevant documents in the database for the three-year period.

Subsequently, BBS searches were conducted to maximize precision rather than recall. These searches were constructed and modified to focus on documents containing all facets and are termed the BBS precision searches. See Appendix B for high precision search strategies.

The same four questions formed the basis of searches in WAIS. Initially, three searches were run on each question. The first search was a keyword search using an abbreviated set of terms from the query; in the discussion that follows this search is called the Terse search. These queries ranged in length from five to eleven terms. The second search was a keyword search using a more inclusive set of terms; it is called the Verbose search. These queries ranged in length from 25 to 42 terms. See Appendix C for the WAIS search strategies. The third search was a Boolean search, formulated as close as possible to the Boolean searches performed in Dialog, although it was impossible to duplicate the searches exactly. Only one Boolean search was successful; the other three searches did not produce usable results (timed out) in spite of multiple efforts. Because there was data from only one Boolean search, the data were not included in the analysis.

The citation sets retrieved using WAIS were combined into a master set for each question. The participants were asked to rate the relevance of each citation in the set, using the same five-point scale. In each of the four cases, the WAIS searches produced citations rated as 4 "Relevant" or 5 "Highly Relevant" that were not retrieved by the BBS searches. Seventeen items retrieved by both systems and for which the relevance judgements differed enough to affect the interpretation were eliminated from the database. The resulting sets of citations are the basis for the data analysis.

Two additional WAIS searches were run on each question. These searches utilized the relevance feedback function of WAIS in order to refine the retrieved set of citations. In each case, up to five citations from the WAIS search that were rated "Very Relevant" were designated as example citations, and the search was run again. Since there are many variations on how relevance feedback may be used and it is most appropriate for end users themselves to make judgments about what documents to feed back, this procedure must be taken as exploratory at best.

3. Results

3.1. Comparison BBS and WAIS Results

3.1.1. Comparisons Based on Precision

The distribution of citations by relevance judgement for all searches is shown in Table 1. The data for relevance judgments were recoded to produce three categories, "Not Relevant" (1 or 2), "Somewhat Relevant" (3), and "Highly Relevant" (4 or 5). For each question, the number of citations and number judgments in each relevance category are given for the BBS recall

search, BBS precision search, WAIS terse search, and WAIS verbose search. Note that percentage values in the “high” category represent precision values.

In all questions, the precision results for the WAIS searches fell between the high recall and high precision results for the BBS searches. Since in practice recall and precision are inversely related, it would be highly surprising if a system that ranks output and uses a cutoff limit did not offer better precision than a high recall BBS search.

Table 1: Relevance Judgments by Search

QUESTION 1	NOT		SOME		HIGH		TOTAL RECORDS
BBS Recall	193	(80%)	18	(7%)	32	(13%)	245
BBS Precision	2	(25%)	0		6	(75%)	8
WAIS Terse	15	(34%)	7	(16%)	22	(50%)	44
WAIS Verbose	20	(44%)	8	(18%)	17	(38%)	45
QUESTION 2							
BBS Recall	57	(12%)	257	(52%)	176	(36%)	490
BBS Precision	3	(18%)	0		14	(82%)	17
WAIS Terse	4	(10%)	21	(53%)	15	(38%)	40
WAIS Verbose	4	(10%)	17	(44%)	18	(46%)	39
QUESTION 3							
BBS Recall	735	(93%)	26	(3%)	43	(5%)	804
BBS Precision	9	(39%)	3	(13%)	11	(48%)	23
WAIS Terse	21	(48%)	12	(27%)	11	(25%)	44
WAIS Verbose	36	(80%)	4	(9%)	5	(11%)	45
QUESTION 4							
BBS Recall	196	(81%)	10	(4%)	35	(15%)	241
BBS Precision	26	(68%)	0		12	(32%)	38
WAIS Terse	30	(67%)	5	(11%)	10	(22%)	45
WAIS Verbose	18	(40%)	23	(51%)	4	(9%)	41

As expected, the precision values for the WAIS searches were above those of the high recall BBS search. The precision values for the WAIS searches were consistently below the results for the BBS high precision searches. To illustrate these differences, the distributions of judgments across the three categories for each of the four types of searches were compared. Since several cells in the matrix of values for each question contained zeroes or small values, the results for the four questions were aggregated for the Chi Square test. A Chi Square value of 1267.3 ($p < .000$, 6 DF) demonstrates the expected result that the distributions are independent. Thus, the proportions of relevant documents for the four types of search were different, i.e., these four types of search represent different search strategies when taken as a group (comparison of the two WAIS strategies are presented in a subsequent section and indicate that these strategies do not differ).

Several observations can be made from these data. First, the high recall searches done in the BBS retrieved a higher number of relevant documents than the WAIS searches for each of the four questions. This is not surprising since the recall searches retrieved 241, 245, 490, and 804 documents respectively for the four questions and the WAIS searches could return at most 45 documents. The consequence of this is that if users wish to obtain high recall and they are willing to spend the time examining large sets of citations, then a BBS should be strongly considered.

Second, the high precision searches done in the BBS provided better precision results, although in two of the four questions the WAIS searches returned a higher number of relevant items. The implications of these data are less clear but suggest that if users are unwilling to examine even moderately sized document sets, better results may be obtained with a BBS search.

3.1.2. Cases

There were citations retrieved by both systems that were treated differently by the other system. Two of these instances are examined below. They illustrate citations which were retrieved by one system and given high relevance ratings but which were not retrieved by the other system.

Case 1: Retrieved by Boolean-based System. The first case is that of a citation retrieved by the BBS but not by WAIS. Fourteen search terms that were in the WAIS verbose search strategy appear in the citation record. It seems likely, therefore, that the citation was identified by the WAIS system as a candidate for retrieval, but it was not included because it was not in the top 45 citations. The average frequency of occurrence of the terms is two. The terms in the search statement that occurred most frequently in the citation were "finite" and "element." It is possible that these two terms are pervasive enough in the NASA database that their weight is relatively low.

It is important to note that there was no truncation capability in the WAIS implementation used in this study. Only the singular forms of the terms "error" and "grid" were entered in the

search statement, while the plural of each term appears in the citation. Therefore, the terms were not matched by the WAIS system. The lack of this functionality poses a major problem for users; in order to compensate, the user must include both singular and plural forms of all terms, as applicable.

Case 2: Retrieved by WAIS. The second case is for a citation retrieved by WAIS but not by the BBS. This citation has terms which match concepts used in the search statement used by the Boolean-based system. For example, one search statement was matched by the major descriptor "computational grids." Similar matches were found for four other search terms. However, the citation also contains a term that was eliminated from the search statement. The phrase "computational fluid dynamics" was removed from the final search set of the Boolean-based search by using the NOT operator because the set of retrieved citations was extremely large. The term was included in the WAIS search, where set size was not an issue. In retrospect, perhaps some other strategy to limit the set size should have been taken rather than eliminating a search term that retrieved a highly relevant document.

This case is a good example of the pitfalls that confront users and trained searchers in working with a traditional retrieval system in a very large database. From an information point of view, removing the phrase from the final search set was not a good strategy because it eliminated this and, perhaps, other relevant citations. On the other hand, from a practical point of view, a huge citation set creates problems for the user. Even the limited set which excluded this citation contained more than 800 items; without this limitation, the set would have contained approximately 2500 items. Not many users have enough time to consider each citation in such a large set.

3.2. Analysis of WAIS Searches

3.2.1. Effect of Citation Set Size

As described above, a WAIS system presents the user with a limited set of citations ordered by a score which is assumed to reflect relevance to the search statement, with the citation with the highest score at the top of the list. Therefore, the top part of a citation list should be richer in relevant citations than the bottom part.

To explore the distribution of relevant documents in the WAIS ranked document lists, the lists were subdivided into three parts: top, middle, and bottom third of the ranked list. Precision values for these three sets of documents were then computed to determine if there was a higher concentration of relevant documents in the top-ranked set of results. Table 2 presents the precision values for each question. Contrary to expectations that the ranking algorithm should distribute proportionally more relevant documents near the top of the rankings, no apparent pattern of distribution was found.

Table 2. Precision Values for Three Partitions of Ranked Results by Question.

QUESTION	TERSE QUERY	VERBOSE QUERY
Question 1		
Top Third	.53	.27
Middle Third	.38	.47
Bottom Third	.64	.43
Question 2		
Top Third	.55	.55
Middle Third	.36	.60
Bottom Third	.42	.46
Question 3		
Top Third	.27	.25
Middle Third	.27	.15
Bottom Third	.21	.00
Question 4		
Top Third	.33	.07
Middle Third	.07	.20
Bottom Third	.20	.00

A Chi-Square test was used to test whether the distribution of documents by relevance differed among the three subsets. The data from the four questions were combined by type of WAIS search then divided into three subsets, by position. The subsets are the top set (first 15 items), middle set (second 15 items), and bottom set (third 15 items). The results for the Terse and Verbose searches are shown in Table 3.

Table 3. Chi-Square Values for Distribution of Relevant Citations by Position in the Set

SEARCH	VALUE	DF	SIGNIFICANCE
Terse	1.88	4	.757
Verbose	2.59	4	.628

The results illustrated that for both types of query relevant documents were just as likely to occur in the middle and bottom thirds as in the top third of the retrieved document set.

Various WAIS clients offer different cutoff levels; the Macintosh client used here offered a range from 5 to 50 citations. These results suggest that increasing the cutoff level for a WAIS search increases proportionally the relevant citations retrieved at least up to a citation set of 45 items. Conversely, limiting the size of the retrieved set is likely to limit proportionally the number of relevant citations retrieved. This finding raises questions about the relationship between the WAIS score and the actual relevance of a citation as judged by the user. Further analysis of the relationship between relevance judgment and WAIS score is necessary.

In sum, the ranking of documents in the WAIS searches did not distribute relevant documents in decreasing order. There was just as good a chance to find a relevant citation in the bottom third of the 45 retrieved as in the top third. Since the concentrations of relevant documents were good throughout the sets of 45, it seems prudent to provide higher cutoff values for users to choose if they wish.

3.2.2. Effect of Differences in WAIS Search Strategies. Two types of search statements were used for the WAIS searches: terse and verbose (included synonyms and related terms). Chi-Square tests were run on each pair of results to determine whether or not the results of the searches differed in the distribution of citations by relevance. For Question 2, an expected value of less than five was obtained for one-third of the cells; therefore, the analysis for this question was discarded. The Chi-Square values for the other three questions are shown in Table 4.

**Table 4. Chi-Square Values for Distribution of Relevance Judgments
by Type of WAIS Query Statement: Terse vs. Verbose.**

QUESTION	VALUE	DF	SIGNIFICANCE
1	1.41	2	.494
3	15.34	2	.004
4	17.14	2	.000

The Chi-Square value for Question 1 indicates that results of the two WAIS query strategies do not differ. That is, the results of the Terse search and the Verbose search were similar in the distribution of citations by relevance ratings. The results for Questions 3 and 4, however, indicate that there were differences between the results of the searches for each of these questions; however, they are in opposite directions. For question 3, the precision of the terse

query was lower than the precision of the verbose query; and for question 4, the precision of the Terse search was higher than for the Verbose search. Thus, there are no clear indications favoring either of the two strategies for these data.

This result is somewhat surprising because the Verbose search included more terms and should, therefore, have been more representative of the full scope of concepts in the original query. However, it may be that expanding the search statement can dilute the precision of a WAIS search by introducing terms that are less closely related to the core of the query, i.e., more noise. In this implementation of WAIS, it is not possible to weight the search terms or to attach any measure of importance, such as order in the search statement--the WAIS algorithm weights all terms equally. A citation will be retrieved by the total score derived by the algorithm, even if a significant part of the score is contributed by terms that are less important to the query.

3.2.2.1. Effects of Adding Terms

To explore the length of query effects in more detail, WAIS searches were systematically conducted by adding terms one at a time. Figures 2-5 present graphical views of how the number of relevant documents changes as an additional term is added to a WAIS search. The number of relevant documents in the set of 45 retrieved is plotted as each term is added. Thus, for Figure 2, there were 8 relevant documents for the query consisting of only the term "unsteady," six relevant documents for the query "unsteady aerodynamics," and 12 relevant documents for the query "unsteady aerodynamics stall." Frequency of occurrence of the term in thousands is given below each term.

Question 1 was motivated by a somewhat general topic, and the terms and question evolved over the two reference interviews. The dips in the graph (fewer relevant citations among the 45 retrieved) occurred as the frequently occurring and generic (for this database) terms "aerodynamics" (5500 occurrences in 4093 documents) and "air" (24,974 occurrences in 14,049 documents) were added to the query. The most common term "model" (63,547 occurrences in 34,027 documents) added some value since it is part of what may be considered a facet "stall delay model."

In question 2, the frequently occurring term "control" (76,573 occurrences in 27,170 documents) adds value to "flight" (37,273 occurrences in 18,684 documents), but the third term of that facet "system" (87,826 occurrences in 44,492 documents) is too common and increases noise. The next facet, "modern control theory," adds value word-by-word to reach a level almost as good as the simple "flight control" facet. Adding the new facet "flexible aircraft" adds surprisingly little value but does reinforce the need for using both terms of the facet.

Question 3 illustrates the importance of technical terms in this database. The term "grid" (7,513 occurrences in 3,605 documents) is the most salient term, adding most of the relevant documents for the entire search. The term "mesh" (2,310 occurrences in 1,344 documents), although relatively rare, adds considerable noise, perhaps due to its multiple technical usages.

Figure 2

WAIS Search - Question 1

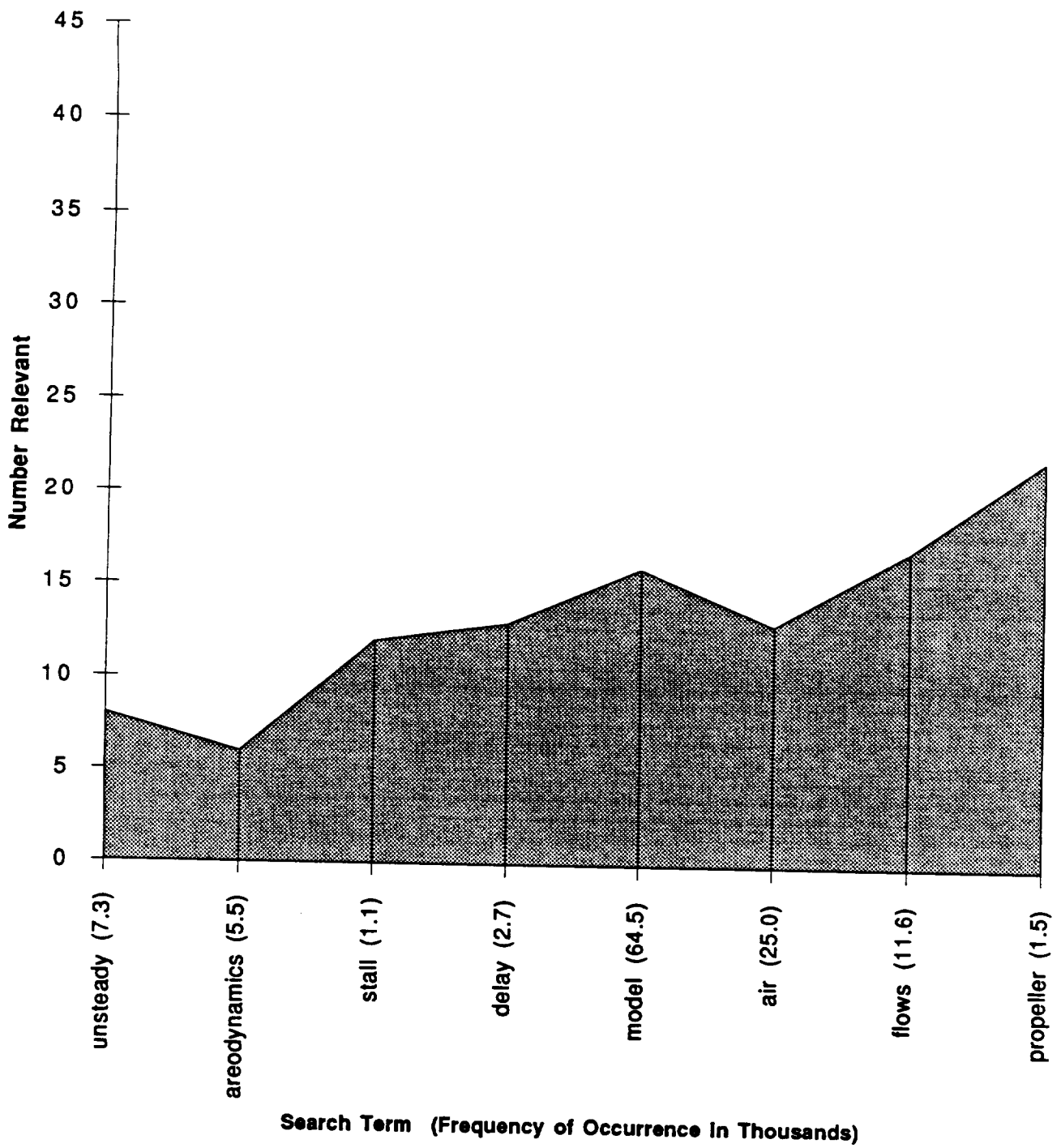


Figure 3

WAIS Search - Question 2

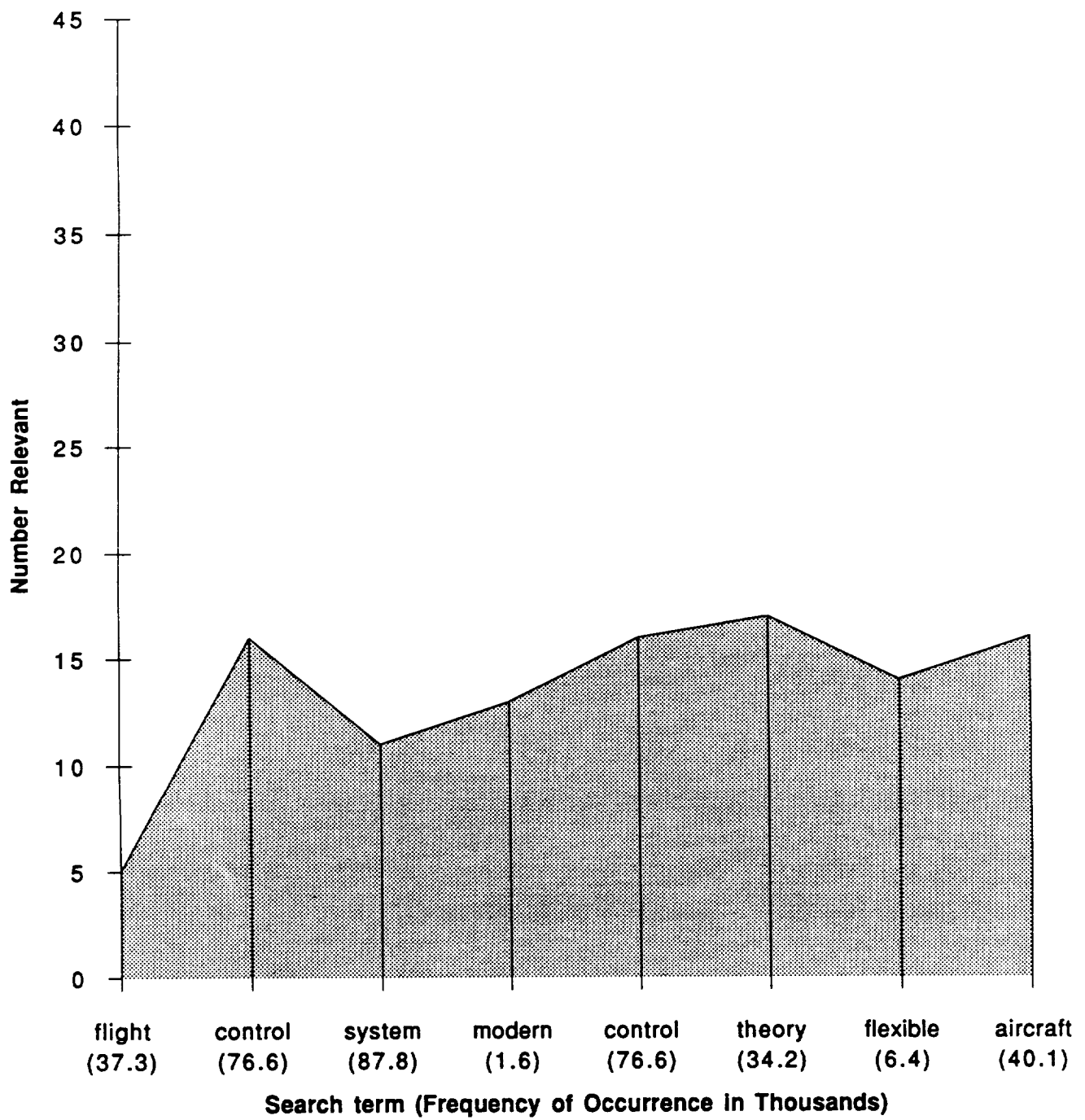


Figure 4

WAIS Search - Question 3

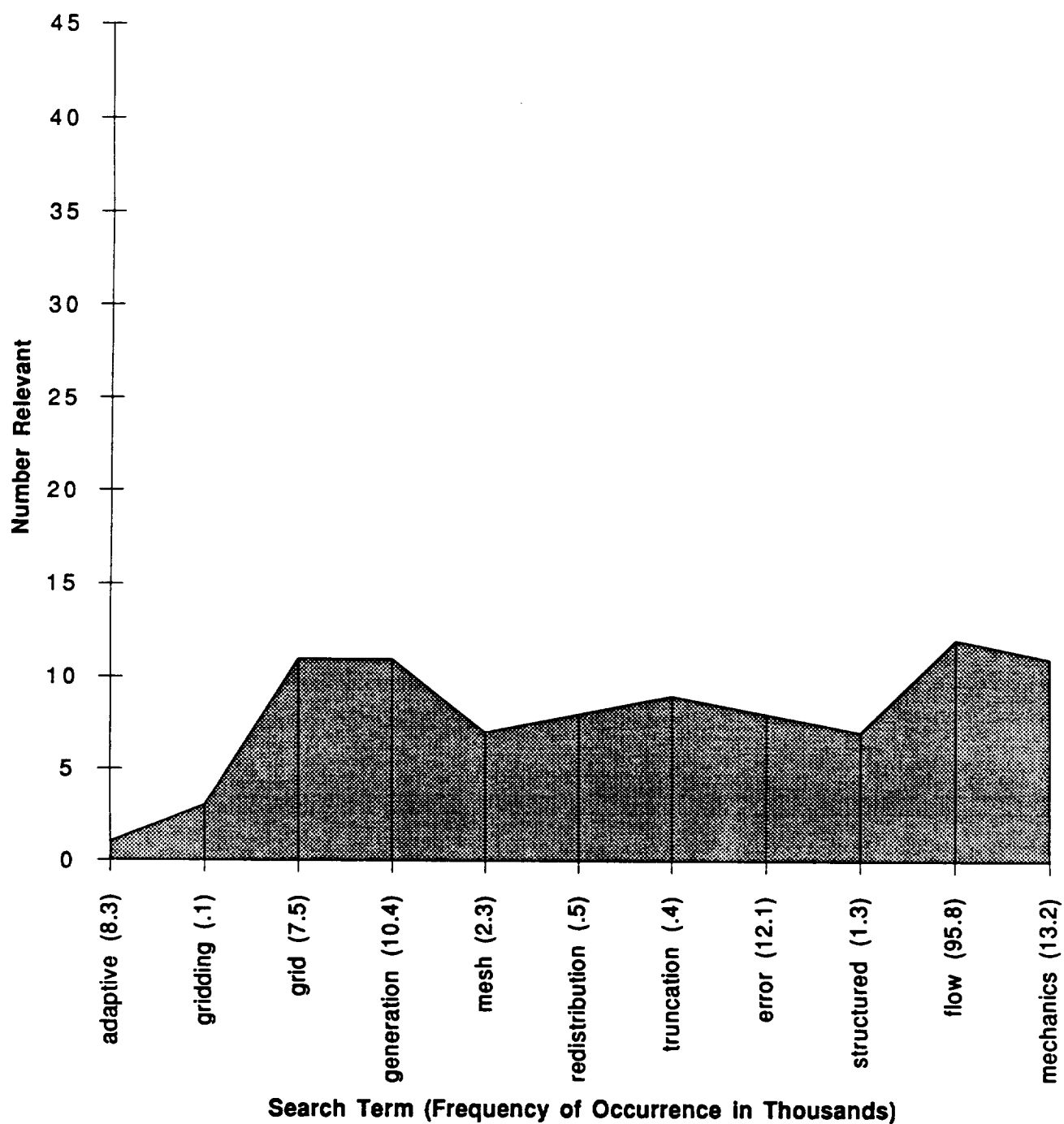
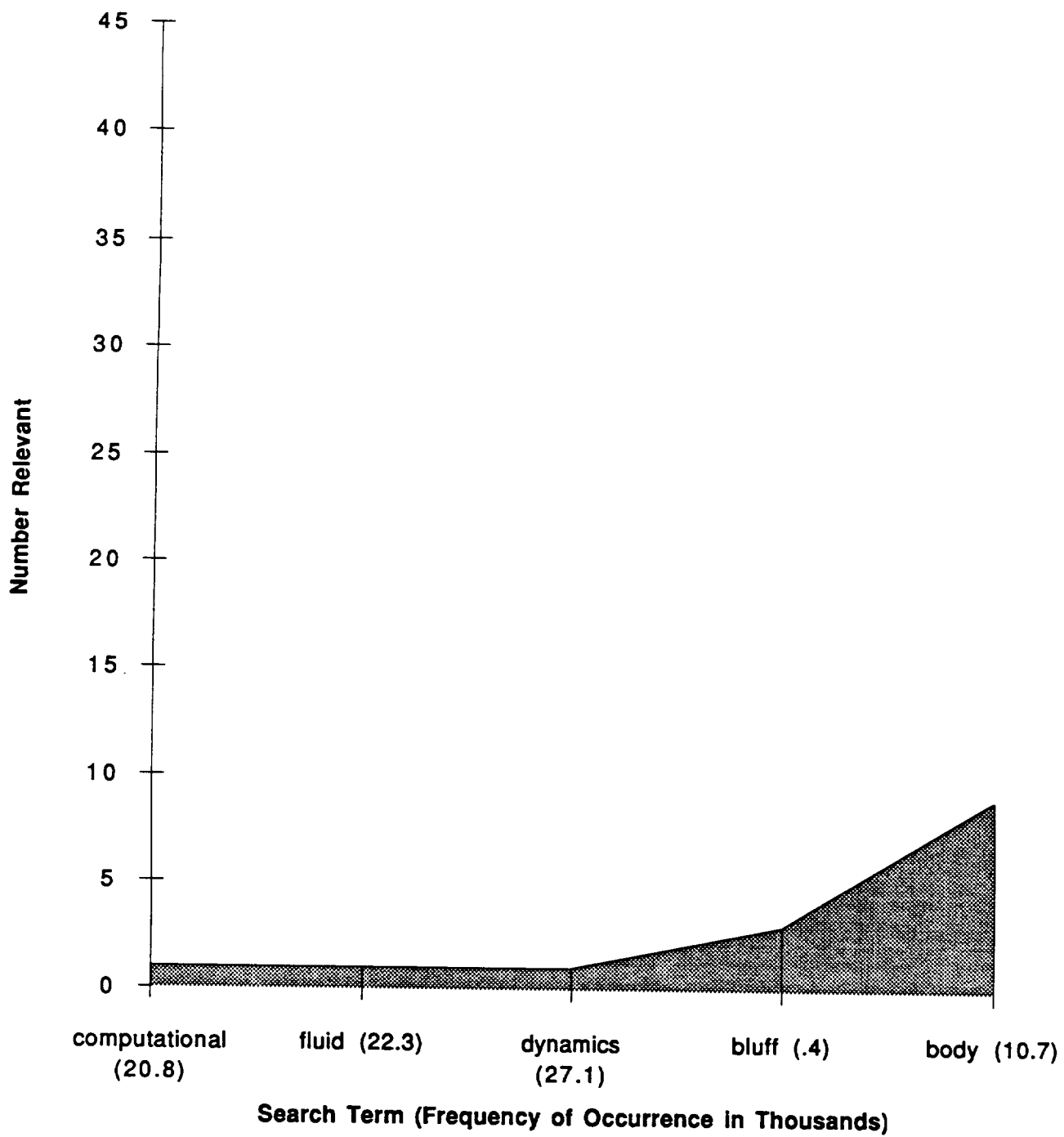


Figure 5

WAIS Search - Question 4



Little value is added as additional generic terms are added until the enormously frequently occurring but technically important term "flow" (95,802 occurrences in 28,340 documents) is added to the query.

Question 4 illustrates how a common facet, "computational fluid dynamics," (computational occurs 20,767 times in 14,461 documents; fluid occurs 22,250 times in 13,977 documents; and dynamics occurs 27,051 times in 19,588 documents) is not helpful but the specific facet, "bluff body," (bluff occurs 373 times in 191 documents; body occurs 10,652 times in 6,412 documents) does yield some positive results. Examining ratios of total occurrences to the number of documents having occurrences is suggestive. Recall may be improved when these ratios are relatively high (e.g., model, control, grid, and flow improve recall and have ratios of 2 or higher) and the occurrences are fairly high. It may be useful to examine whether such ratios are useful for query formulation (since these could be provided to the user during query formulation automatically) and whether some tolerance levels for usefulness can be developed.

This discussion illustrates the importance of mapping user need to facets and then considering which terms of a facet should actually be included in the query. This is certainly the case in BBS search strategy, but the use of controlled vocabularies makes these mapping decisions more tractable. For a system like WAIS, where the interplay between terms, facets, and the content of the entire database is so complex, the end-users special domain knowledge and immediately available intelligence seem necessary to give appropriate results. The end user's understanding of the information problem, the vocabulary of the field, and the scope of the database may substitute for query formulation tools such as thesauri.

3.2.3. Effect of Relevance Feedback. WAIS allows a user to use citations retrieved in one search as feedback for subsequent searches. The user marks citations and asks for other citations that are similar. Relevance feedback should re-sort the citations to bring more relevant items to the top of the ranked list, thus increasing both the recall and the precision within the cutoff value.

Relevance feedback was used with each of the eight WAIS searches. In each case, the documents designated as examples for the new iteration were the five documents with the highest WAIS scores that had been rated as "Very Relevant" by the requestor. (In the WAIS search which returned only four documents rated as "Very Relevant," only four documents were designated.) The results of the new search were compared with the results of the original WAIS search. It is important to iterate that this was a simplistic approach to relevance feedback. First, several different approaches should be taken (e.g., how many documents to feedback, feedback of document sections or words as well as citations, etc.). Second, relevance feedback is best done by end users, a condition made impossible by the artificial constraints of this study.

In six of eight searches, the results using relevance feedback were the same as the results from the original search. There were no differences in the specific citations retrieved nor in

the order of presentation of the citations. However, the results for two searches, both for Question 4, were different. The distribution of relevant citations for these two searches is shown in Table 5.

Table 5. Relevance Judgments for Searches with Relevance Feedback for Question 4.

SEARCH	NOT RELEVANT		SOMEWHAT RELEVANT		VERY RELEVANT	
	NO.	%	NO.	%	NO.	%
Terse with Relevance Feedback	29	(64%)	7	(16%)	9	(20%)
Verbose with Relevance Feedback	28	(62%)	15	(33%)	2	(4%)

A Chi-Square test was used to test the expectation that the results of the searches using relevance feedback differed from the original WAIS searches. For the Verbose search, an expected cell frequency of less than five was found for two of the six cells; therefore, the results are not reported. The results for the Terse search yield a value of .40 [$p=.82$]. Thus, there are no significant differences between the original WAIS search and the search using relevance feedback.

However, other comparisons are of interest. The search with relevance feedback for the Terse search yielded six new citations out of a total retrieved set of 45 citations. None of the new citations was judged as "Very Relevant." Therefore, relevance feedback did not increase recall. The precision value for the Terse search with relevance feedback is .20, which is approximately the same as the precision value for the original Terse search, .22. The Verbose search with relevance feedback yielded 20 new citations, none of which was judged "Very Relevant." The precision value for the Verbose search with relevance feedback is .04, which is much lower than the precision value for the original Verbose search, .09.

The use of relevance feedback did not increase recall or precision in either of the two searches, although this result must be qualified by the small number of questions tested and the use of four or five citations as a whole as feedback. More extensive analyses of relevance feedback are needed to determine when and how it is most useful.

4. Summary and Discussion

4.1. Limitations of This Work

Although simple Boolean-based retrieval systems (BBS) have been the standard in operational systems for many years, today's systems have been enhanced to provide capabilities such as field limits, proximity qualification, and term weighting in the form of major or minor index

terms. Term weighting and the new rank or target features of Dialog were not used; therefore, the Dialog BBS system was not fully exploited. Likewise, the WAIS system was not fully exploited. One of the most basic features of WAIS is its ability to distribute queries to multiple servers; this feature was not used at all. Likewise, the highly promoted “natural language” feature was not used; strings of terms and phrases (structured queries) were used rather than full-sentence queries or English clauses. Since both systems are evolving, the results from this study must be considered in the context of the current state of the art. This is particularly crucial for the WAIS system that has a relatively small experience base--a fact that makes explorations such as this one more important since findings can be used to influence subsequent iterations.

In addition to these limits on how the systems were used, this study was limited by the small number of questions, the fact that relevance judgments were made only by the requestor rather than a panel of experts, and the often-noted problems of making relevance judgments in general.

As stated earlier, the objective of this investigation was to compare the capabilities of Boolean and vector-based retrieval systems, emphasizing the strengths and appropriate uses of each. The preliminary results of this investigation and the experience gained in working with both systems on the same questions provide information useful in reaching this goal and point out questions needing further study. Certain strengths and weaknesses of each system can be discussed within the context of these findings, with particular emphasis given to WAIS.

4.2. Pros and Cons of BBS.

BBSs offer powerful search capabilities for professional searchers. The main strengths are related to high levels of control over how search is conducted. The system can yield high recall values if high recall strategies are used, and high precision if high precision strategies are used. Thus, BBSs provide a good range of features for constructing searches customized to specific user needs. Features such as proximity operators and file limits give the searcher greater control in constructing a search query and allow results to be interpreted directly. Additionally, there is a large base of experience in using this type of system and extensive research on various search techniques and strategies.

Limitations of BBS include the “flip side” of multiple features and good control--high levels of expertise are required. Searches require a considerable investment of proximity resources--time, effort, and money. The searchers in this project spent an average of three hours preparing for each search. Each search consisted of as many as 56 search statements and required at least an hour in an online session. Additionally, the size of the retrieved set can be very large, particularly when trying to maximize recall. The case cited earlier points out a trade-off encountered in trying to limit set size.

4.3. Problems with WAIS

This study illustrated several problems with the WAIS system. The lack of tools, such as proximity operators other than immediate adjoining to the right, means that the user has less

control over a search statement. Use of relevance feedback should be a compensating feature, but the results from relevance feedback were not encouraging. Secondly, the established size of the citation set artificially limits the number of relevant citations retrieved. Thirdly, the experience base, documentation, and training for vector-based systems are undeveloped, at this time. Some of these problems are likely due to the limited nature of the investigation and problems with server or client implementations, but others require longer-term consideration. First, WAIS provides a "black box" effect for the user. Users put in queries and get results based upon many hidden computations. For end users this may be just what is needed if performance can be demonstrated to be good. For professional intermediaries, however, using WAIS can be quite frustrating since it is impossible to deduce exactly how results were obtained. Furthermore, searchers have good control over how they conduct searches in a BBS; e.g., they can design queries to maximize either precision or recall. Strategies for constructing queries, setting cutoffs and using relevance feedback with WAIS are yet to be identified and tested for different types of needs.

Second, the ranking algorithm used in WAIS yielded disparate results in this study. Substantial additions and modifications may be needed if WAIS is to be used in high-performance environments where results are mission-critical. This has been recognized by WAIS Inc. since the commercial version of the server provides for Boolean operators and a query report that gives posting data. Continued movement toward a more hybrid approach to information retrieval seems prudent if WAIS is to be useful for end users and professional intermediaries alike. More problematic is the way that relevance feedback is handled. At present, users have no control over how weights are assigned--a double-edged sword from learnability and user control perspectives. The low weights given to terms in the feedback query compared to terms in the original query reduced the effectiveness of relevance feedback in query refinement. Likewise, there is very poor control for setting cutoff values which affects both relevance judgments for ranked sets and feedback decisions. Also, distinctions between different iterations of a search are difficult to make unless each iteration is saved and then compared separately with a word processing or text management package. Adding new features for setting feedback parameters and for manipulating intermediate result sets will occupy the research and development community for some time to come.

4.4. Potentials with WAIS

Several positive aspects of using WAIS were illustrated by this work. First, the system yields generally acceptable precision values for little user effort. Second, less time and effort are required to conduct a search in WAIS than in the BBS. The time required to conduct a WAIS search ranged from approximately 40 seconds to slightly over 60 seconds. It must be noted, of course, that the preliminary work of structuring the search had been done for the BBS searches and was not counted as part of the WAIS search process. Also, WAIS utilizes natural language expressions as search queries, which should minimize the time needed to structure search statements. Third, the established size of the citation set provides a means of controlling the number of document records that the requestor must review, which is valuable in producing results that are immediately useful.

Although it is sometimes the case that no documents are returned in a WAIS search, it is much more likely that something is found that can serve as a starting point for subsequent search or browsing. This is in contrast to BBS systems such as OPACs and Grateful Med that typically yield "no hits" for about one-third of all end user searches. Thus, WAIS offers users starting points for interactive sessions. Although the purpose of this study centered on retrieval performance rather than the interface, usability effects were clearly apparent and represent significant advantages over BBS. First, there is no query language to learn--a clear advantage for novice and occasional users. Second, WAIS is easy to use, offering direct manipulation interaction styles in the Macintosh and X-Windows clients. These clients invite exploration and interaction and allow editing/cutting and pasting operations to be leveraged as reinforcement to continuous interactivity rather than as simple short-cuts for discrete, linear search.

4.5. Implications

Highly interactive systems invite end users to do their own searching and offer massive amounts of information. Although much time can be spent exploring with WAIS (other systems such as Mosaic depends almost entirely on exploration), questions about efficiency and cost-effectiveness will become more critical as these systems are used in commercial settings and as the costs of network access and use become less transparent.

There are two sets of problems that require research. First, it seems clear that highly interactive front-ends such as WAIS demand new information-seeking strategies. Just as it took time and experience for the online community to develop and teach strategies for BBS such as "building block," "successive fraction," "pearl growing," and "iterative scanning" (Hawkins & Wager, 1982), it will take time to discover strategies that serve different search purposes and users in WAIS and other emerging systems. For example:

- What effects will query length have in such environments, and how should users control relevance feedback?
- Will domain experts use relevance feedback differently than intermediaries?
- Should term weighting be used, and if so, how?
- How will multiple servers affect results?

Just as intermediaries have developed divide and conquer strategies to handle problems with many facets using a BBS, there may be a need for staged strategies for different databases or customization of queries for specific databases using WAIS. Although WAIS clients provide options to display results by server, this is a simple beginning to distinguish and develop more carefully targeted revisions/feedback to specific servers. Finally, better ways are needed to keep the user informed of how the search is progressing and why results have been obtained. Intermediate posting data and sophisticated query reports may be helpful here.

Second, there is a need for new evaluation metrics that address the interactive nature of systems like WAIS. Variables such as time, number of queries, number of iterations, number of screens/windows displayed, number or distribution of records displayed or saved, cost, and satisfaction may take on new meanings in such environments. New variables such as number

of servers queried, number of servers returning results, and filtering values for different servers may be needed. As electronic environments become more seamlessly integrated, it may become feasible to trace how information actually gets integrated into user work (e.g., text or citations cut and pasted into documents, figures imported into spreadsheets or local databases, etc.) to gain a fuller understanding of how information seeking supports user work. It will become more feasible to assess where information objects came from as electronic documents are constructed as a series of links between existing and original text, images, and other objects. Some attention to assessing the overall process rather than simply the products of searching must also be considered (e.g., search patterns from symbolic or graphical perspectives, Lin, Liebscher, & Marchionini, 1991).

The results summarized here demonstrate some of the possibilities as well as problems that systems such as WAIS provide for the IR community. Rather than aiming to compare systems on simplistic metrics rooted in tradition, we are challenged to develop systems that apply different techniques and interfaces and to test those systems from formative as well as comparative perspectives. This effort used comparison as the basis for better understanding a specific innovative system. The results temper the "hype" associated with new technologies and raise questions about assumed performance and features. It suggests directions for improving this particular system in subsequent iterations, but more importantly, raises issues about what types of questions seem promising for research, development, and evaluation.

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Appendix A: BBS Recall Search Strategies

Subject One

DIALOG Recall Search Statement:

File 108:AEROSPACE 62-93/9306B2

Set Items Description

--- ----

?ss unstead?

Search the unsteady state concept

S1 20326 UNSTEAD?

?ss s1()(state? or flow? or aerodynam? or pressure?)

20326 S1

S2 153877 STATE?

S3 247128 FLOW?

S4 58099 AERODYNAM?

S5 150226 PRESSUR?

S6 14334 S1()(STATE? OR FLOW? OR AERODYNAM? OR PRESSUR?)

?ss turbulen?

S7 70594 TURBULEN?

?ss s7()(flow? or wake? or model? or effect?)

70594 S7

247128 S3

S8 12835 WAKE?

S9 335200 MODEL?

S10 455590 EFFECT?

S11 29748 S7()(S3 OR WAKE? OR MODEL? OR EFFECT?)

?ss s7()boundar?()layer?

70594 S7

S12 135730 BOUNDAR?

S13 121839 LAYER?

S14 11509 S7()BOUNDAR?()LAYER?

?ss nonstation?

S15 4758 NONSTATION?

?ss non()station?

S16 37066 NON

S17 66489 STATION?

S18 525 NON()STATION?

?ss s15 or s18

4758 S15

525 S18

S19 5108 S15 OR S18

?ss s19()s7
 5108 S19
 70594 S7
 S20 34 S19()S7

?ss s1 or s5 or s6 or s7 or s11 or s14 or s19 or s20

Combine synonyms for the unsteady state concept

20326 S1
 150226 S5
 14334 S6
 70594 S7
 29748 S11
 11509 S14
 5108 S19
 34 S20
 S21 223959 S1 OR S5 OR S6 OR S7 OR S11 OR S14 OR S19 OR
 S20

?ss s21 or (model?())air()flow?) or (air()flow?)

223959 S21
 S22 335200 MODEL?
 S23 115109 AIR
 S24 247128 FLOW?
 S25 1 MODEL?(W)AIR(W)FLOW?
 S26 115109 AIR
 S27 247128 FLOW?
 S28 7465 AIR(W)FLOW?
 S29 227922 S21 OR (MODEL?())AIR()FLOW?) OR (AIR()FLOW?)

?ss s29/de*

Sift to see how many citations were pulled from major descriptors

S30 83616 S29/DE*

?ss s29/de

Sift to see how many citations were pulled from all descriptors

S31 164207 S29/DE

?ss model?

Search the mathematical/computer models concept

S32 335200 MODEL?

?ss math?()s32

S33 166591 MATH?
 335200 S32
 S34 87641 MATH?()S32

?ss computer?()s32
S35 199247 COMPUTER?
335200 S32
S36 4145 COMPUTER?()S32

?ss (numeric?(2n)s35)()s32
S37 131256 NUMERIC?
199247 S35
335200 S32
S38 34 (NUMERIC?(2N)S35)()S32

?ss digit?()simulat?
S39 61786 DIGIT?
S40 126899 SIMULAT?
S41 5918 DIGIT?()SIMULAT?

?ss s32 or s34 or s36 or s38 or s40 or s41

*Combine synonyms for the mathematical/
computer models concept*

335200 S32
87641 S34
4145 S36
34 S38
126899 S40
5918 S41
S42 408079 S32 OR S34 OR S36 OR S38 OR S40 OR S41

?ss s42/de*

*Sift to see how many citations were pulled
from major descriptors*

S43 109315 S42/DE*

?ss s42/de

*Sift to see how many citations were pulled
from all descriptors*

S44 237530 S42/DE

?ss propell?

Search the propeller state concept

S45 29531 PROPELL?

?ss high()solid?()s45
S46 289326 HIGH
S47 86661 SOLID?
29531 S45
S48 2 HIGH()SOLID?()S45

?ss s45()blade?

29531 S45
S49 23717 BLADE?
S50 1027 S45()BLADE?

?ss (compress? or fan? or rotor? or stator or turbine?)(s49
S51 54002 COMPRESS?
S52 6742 FAN?
S53 22141 ROTOR?
S54 1985 STATOR
S55 30977 TURBINE?
23717 S49
S56 15931 (COMPRESS? OR FAN? OR ROTOR? OR STATOR OR
TURBINE?)(S49

?ss wind()s55
S57 85351 WIND
30977 S55
S58 2248 WIND()S55

?ss (s57()power?)(utiliz? or generat?)
85351 S57
S59 146391 POWER?
S60 63826 UTILIZ?
S61 121687 GENERAT?
S62 89 (S57()POWER?)(UTILIZ? OR GENERAT?)

?ss streamline?()bod?
S63 4040 STREAMLIN?
S64 93722 BOD?
S65 275 STREAMLIN?()BOD?

?ss engine()part?
S66 47311 ENGINE
S67 296392 PART?
S68 3034 ENGINE()PART?

?ss windmill?
S69 886 WINDMILL?

?ss s45 or s48 or s49 or s50 or s56 or s58 or s62 or s65 or s68
or s69 or s55

Combine synonyms for the propeller concept

29531 S45
2 S48
23717 S49
1027 S50
15931 S56
2248 S58
89 S62

275 S65
 3034 S68
 886 S69
 30977 S55
 S70 72042 S45 OR S48 OR S49 OR S50 OR S56 OR S58 OR S62
 OR S65 OR S68 OR S69 OR S55

?ss s70/de*

*Sift to see how many citations were pulled
 from major descriptors*

S71 43374 S70/DE*

?ss s70/de

*Sift to see how many citations were pulled
 from all descriptors*

S72 59245 S70/DE

?ss delay?

Search the stall delay concept

S73 18147 DELAY?

?ss stall?()s73

S74 4056 STALL?

18147 S73

S75 25 STALL?()S73

?ss aerodynam?()(s74 or stabil?)

S76 58099 AERODYNAM?

4056 S74

S77 135757 STABIL?

S78 4726 AERODYNAM?()(S74 OR STABIL?)

?ss engine?()fail?

S79 155807 ENGINE?

S80 45414 FAIL?

S81 1209 ENGINE?()FAIL?

?ss (aircraft? or airplane?())perform?

S82 121142 AIRCRAFT?

S83 6021 AIRPLANE?

S84 228951 PERFORM

S85 5671 (AIRCRAFT? OR AIRPLANE??())PERFORM?

?ss stop???? ?

S86 5945 STOP???? ?

?ss lateness

S87 22 LATENESS

?ss time()lag?

S88 251319 TIME?

S89 20890 LAG?

S90 7038 TIME?()LAG?

?ss s73 or s74 or s75 or s77 or s78 or s81 or s85 or s86 or s87
or s90

Combine synonyms for the stall delay concept

18147 S73

4056 S74

25 S75

135757 S77

4726 S78

1209 S81

5671 S85

5945 S86

22 S87

7038 S90

S91 168912 S73 OR S74 OR S75 OR S77 OR S78 OR S81 OR S85
OR S86 OR S87 OR S90

?ss s91/de*

*Sift to see how many citations were pulled
from major descriptors*

S92 73227 S91/DE*

?ss s91/de

*Sift to see how many citations were pulled
from all descriptors*

S93 121954 S91/DE

?ss s30 and s43 and s71 and s92

*Combine the four separate concepts together
(unsteady state, mathematical/computer
models, propeller, and stall delay) for the
sets with major descriptor terms*

83616 S30

109315 S43

43374 S71

73227 S92

S94 11 S30 AND S43 AND S71 AND S92

?ss s31 and s44 and s72 and s93

*Combine the four separate concepts together
(unsteady state, mathematical/computer
models, propeller, and stall delay) for the
sets with all descriptor terms*

164207 S31

237530 S44

59245 S72
121954 S93
S95 243 S31 AND S44 AND S72 AND S93

?ss s29 and s42 and s70 and s91

*Combine the four separate concepts together
(unsteady state, mathematical/computer
models, propeller, and stall delay) for the
sets with natural language terms*

227922 S29
408079 S42
72042 S70
168912 S91
S96 1334 S29 AND S42 AND S70 AND S91

?ss ud=9001:9212b2

Set the update restriction of 1990-1992

S97 205080 UD=9001:9212B2

?ss s94 and s97

Limit the major descriptor citations by date

11 S94
205080 S97
S98 3 S94 AND S97

?ss s95 and s97

Limit all descriptor citations by date

243 S95
205080 S97
S99 48 S95 AND S97

?ss s96 and s97

Limit the natural language citations by date

1334 S96
205080 S97
S100 244 S96 AND S97

?ss s99 not s98

*Compared sets by NOTing to compare
citations pulled in through major descriptors,
all descriptors, and natural language :*

48 S99
3 S98
S101 45 S99 NOT S98

?ss s100 not (s98 or s101)
244 S100

3 S98
45 S101
S104 196 S100 NOT (S98 OR S101)

?logoff

Subject Two

DIALOG Recall Search Statement:

File 108:Aerospace Database 1962-1993/Jul B1

Set	Items	Description
---	----	-----

Expand on select authors' names and titles to look at indexing

S1	10	AU="MYERS, THOMAS T."
S2	20	AU=MCRUER, D.
S3	47	AU=MCRUER, D. T.
S4	5	AU=MCRUER, DUANE
S5	16	AU=MCRUER, DUANE T.
S6	88	E4-E7
S7	2	AU=THOMSON, P. F.
S8	2	AU=THOMSON, P. J.
S9	4	E4-E5
S10	2	AU=ASHKENAS, I.
S11	42	AU=ASHKENAS, I. L.
S12	4	AU=ASHKENAS, IRVING L.
S13	48	E6-E8
S14	16	AU=DOYLE, J.
S15	32	AU=DOYLE, J. C.
S16	48	E4-E5
S17	15649	ADVANCE?/TI
S18	6969	PILOT?/TI
S19	40127	AIRCRAFT/TI
S20	30490	FLIGHT/TI
S21	61210	CONTROL/TI
S22	181326	SYSTEM?/TI
S23	2	ADVANCE?()PILOT?()AIRCRAFT()FLIGHT()CONTROL() SYSTEM?/TI
S24	2	RN=STI-TR-1228-1

?ss modern()control?()theor?

Search the modern control theory concept

S25	9189	MODERN
S26	235735	CONTROL?
S27	304734	THEOR?
S28	239	MODERN()CONTROL?()THEOR?

?ss mcl

S29	77	MCT
-----	----	-----

?ss control()theor?

S30 235735 CONTROL?
 S31 304734 THEOR?
 S32 13852 CONTROL?()THEOR?

?e h-in

Expand on h-infinity control in the basic index

Ref	Items	Index-term
E1	8	H-BETA LINE
E2	4	H-GAMMA LINE
E3	0	*H-IN
E4	53	H-INFINITY CONTROL
E5	59	H-LINE
E6	53	H-WAVE
E7	10	H-1 ENGINE
E8	7	H-1 ROCKET ENGINE
E9	3	H-126 AIRCRAFT
E10	1	H-126 JET FLAP AIRCRAFT
E11	1	H-13 AIRCRAFT
E12	6	H-17 HELICOPTER

?ss e4

Select the appropriate term

S33 53 "H-INFINITY CONTROL"

?ss h()infini?()control?

S34 40267 H
 S35 23343 INFINIT?
 S36 235735 CONTROL?
 S37 247 H()INFINIT?()CONTROL?

?ss h()infini?

S38 40267 H
 S39 23343 INFINIT?
 S40 635 H()INFINIT?

?e h-2

Expand on h-2 control in the basic index

Ref	Items	Index-term
E1	6	H-17 HELICOPTER
E2	1	H-19 HELICOPTER
E3	0	*H-2
E4	1	H-25 HELICOPTER
E5	1	H-34 HELICOPTER
E6	1	H-43 HELICOPTER
E7	82	H-53 HELICOPTER
E8	7	H-54 HELICOPTER
E9	14	H-56 HELICOPTER
E10	43	H-60 HELICOPTER

E11 304 HA
E12 11 HAA

?e h 2

Ref	Items	Index-term
E1	13	H REGION
E2	161	H WAVES
E3	0	*H 2
E4	63	H-ALPHA LINE
E5	8	H-BETA LINE
E6	4	H-GAMMA LINE
E7	53	H-INFINITY CONTROL
E8	59	H-LINE
E9	53	H-WAVE
E10	10	H-1 ENGINE
E11	7	H-1 ROCKET ENGINE
E12	3	H-126 AIRCRAFT

?ss h()2()control?

S41 40267 H
S42 195123 2
S43 235735 CONTROL?
S44 3 H()2()CONTROL?

?ss s28 or s29 or s32 or s33 or s37 or s40 or s44

Combine synonyms for the modern control theory concept

239 S28
77 S29
13852 S32
53 S33
247 S37
635 S40
3 S44
S45 14284 S28 OR S29 OR S32 OR S33 OR S37 OR S40 OR S44

?ss s45/de*

Sift through citations in which these concepts were major descriptors

S46 7280 S45/DE*

?ss s45/de

Sift through those citations in which these concepts were major or minor descriptors

S47 12827 S45/DE

?ss flight?()simulat?

Searching the flight control concept

S48 110968 FLIGHT?

S49 126899 SIMULAT?
S50 8968 FLIGHT?()SIMULAT?

?ss flight?()control?()design?
S51 110968 FLIGHT?
S52 235735 CONTROL?
S53 260987 DESIGN?
S54 125 FLIGHT?()CONTROL?()DESIGN?

?ss flight?()control?()theor?
S55 110968 FLIGHT?
S56 235735 CONTROL?
S57 304734 THEOR?
S58 5 FLIGHT?()CONTROL?()THEOR?

?ss flight?()control?
S59 110968 FLIGHT?
S60 235735 CONTROL?
S61 10621 FLIGHT?()CONTROL?

?ss active?()control?
S62 104513 ACTIV?
S63 235735 CONTROL?
S64 3531 ACTIV?()CONTROL?

?ss act
S65 4525 ACT

?ss activ?()control?()technol?
S66 104513 ACTIV?
S67 235735 CONTROL?
S68 108774 TECHNOL?
S69 231 ACTIV?()CONTROL?()TECHNOL?

?ss activ?()control?()tech?
S70 104513 ACTIV?
S71 235735 CONTROL?
S72 344509 TECH?
S73 270 ACTIV?()CONTROL?()TECH?

?ss flight?()control?()system?
S74 110968 FLIGHT?
S75 235735 CONTROL?
S76 509309 SYSTEM?
S77 2896 FLIGHT?()CONTROL?()SYSTEM?

?ss control?()system?()design?
S78 235735 CONTROL?

S79 509309 SYSTEM?
S80 260987 DESIGN?
S81 10793 CONTROL?()SYSTEM?()DESIGN?

?ss aircraft?()control?
S82 121142 AIRCRAFT?
S83 235735 CONTROL?
S84 6658 AIRCRAFT?()CONTROL?

?ss advanc?(2w)s82(advanc?(2w)s82)(5n)s54
S85 47210 ADVANC?
121142 S82
125 S54
S86 0 (ADVANC?(2W)S82)(5N)S54

?ss (robust(5n)multivari?)(7n)(control?()method?)
S87 5109 ROBUST
S88 5523 MULTIVARI?
S89 235735 CONTROL?
S90 351482 METHOD?
S91 2 (ROBUST(5N)MULTIVARI?)(7N)(CONTROL?()METHOD?)

?ss (single or singular?)(w)(value?(w)base?)(7n)s77
S92 86999 SINGLE
S93 14469 SINGULAR?
S94 145770 VALUE?
S95 216862 BASE?
2896 S77
S96 2 (SINGLE OR SINGULAR?)(W)(VALUE?(W)BASE?)(7N)S77

?ss computer?()simulat?
S97 199247 COMPUTER?
S98 126899 SIMULAT?
S99 43205 COMPUTER?()SIMULAT?

?ss aircraft?()guid?
S100 121142 AIRCRAFT?
S101 34575 GUID?
S102 1478 AIRCRAFT?()GUID?

?ss stabiliz?
S103 25301 STABILIZ?

?ss s50 or s54 or s58 or s61 or s64 or s65 or s73 or s77 or s81
or s84

*Combine synonyms for the flight control
theory concept*

8968 S50
125 S54

5 S58
 10621 S61
 3531 S64
 4525 S65
 270 S73
 2896 S77
 10793 S81
 6658 S84
 S104 38491 S50 OR S54 OR S58 OR S61 OR S64 OR S65 OR S73
 OR S77 OR S81 OR S84

?ss s104 or s82 or s91 or s96 or s99 or s102 or s103

38491 S104
 121142 S82
 2 S91
 2 S96
 43205 S99
 1478 S102
 25301 S103
 S105 201581 S104 OR S82 OR S91 OR S96 OR S99 OR S102 OR
 S103

?ss s105/de*

*Sift through those citations in which these
concepts were major descriptors*

S106 110943 S105/DE*

?ss s105/de

*Sift through those citations in which these
concepts were major or minor descriptors*

S108 161600 S105/DE

?ss (flex? or elast?)(aircraft? or bod? or model? or airplane?)

Search on the flexible aircraft concept

S109 27359 FLEX?
 S110 71257 ELAST?
 S111 121142 AIRCRAFT?
 S112 93722 BOD?
 S113 335200 MODEL?
 S114 6021 AIRPLANE?
 S115 8589 (FLEX? OR ELAST?)(AIRCRAFT? OR BOD? OR MODEL?
 OR AIRPLANE?)

?ss s115()(dynamic? or design? or handl? or model?)

8589 S115
 S116 168075 DYNAMIC?
 S117 260987 DESIGN?
 S118 18085 HANDL?

S119 335200 MODEL?
 S120 405 S115()(DYNAMIC? OR DESIGN? OR HANDL? OR MODEL?)

 ?ss s120()model?
 405 S120
 S121 335200 MODEL?
 S122 354 S120()MODEL?

 ?ss s116()s121
 168075 S116
 335200 S121
 S123 10541 S116()S121

 ?ss s116()system?
 168075 S116
 S124 509309 SYSTEM?
 S125 7219 S116()SYSTEM?

 ?ss transport?()aircraft?
 S126 66796 TRANSPORT?
 S127 121142 AIRCRAFT?
 S128 6061 TRANSPORT?()AIRCRAFT?

 ?ss s127()s121
 121142 S127
 335200 S121
 S129 2726 S127()S121

 ?ss control?()configure?()vehicle?
 S130 235735 CONTROL?
 S131 78429 CONFIGUR?
 S132 53481 VEHICLE?
 S133 600 CONTROL?()CONFIGUR?()VEHICLE?

 ?ss activ?()control?()tech?()s127
 S134 104513 ACTIV?
 S135 235735 CONTROL?
 S136 344509 TECH?
 121142 S127
 S137 2 ACTIV?()CONTROL?()TECH?()S127

 ?ss aeroelastic?
 S138 5395 AEROELASTIC?

 ?ss (structur? or s127 or s130)()stabili?
 S139 282772 STRUCTUR?
 121142 S127
 235735 S130
 S140 135626 STABILI?

S141 15126 (STRUCTUR? OR S127 OR S130)()STABILI?

?ss rigid?()structur?s139

S142 18975 RIGID?

282772 S139

S143 4296 RIGID?()S139

?ss s127()configur?

121142 S127

S144 78429 CONFIGUR?

S145 4300 S127()CONFIGUR?

?ss s115 or s120 or s123 or s125 or s128 or s129 or s133 or s137
or s138

*Combine synonyms for the flexible aircraft
concept*

8589 S115

405 S120

10541 S123

7219 S125

6061 S128

2726 S129

600 S133

2 S137

5395 S138

S146 38615 S115 OR S120 OR S123 OR S125 OR S128 OR S129 OR
S133 OR S137 OR S138

?ss s146 or s141 or s143 or s145

38615 S146

15126 S141

4296 S143

4300 S145

S147 58305 S146 OR S141 OR S143 OR S145

?ss s147/de*

*Sift through those citations in which these
concepts were major descriptors*

S148 30559 S147/DE*

?ss s147/de

*Sift through those citations in which these
concepts were major or minor descriptors*

S149 49829 S147/DE

?ss s46 and s106 and s148

*Combine the separate concepts (modern
control theory, flight control, and flexible*

*aircraft) for those citations in which the
search terms were major descriptors*

7280 S46
110943 S106
30559 S148
S153 201 S46 AND S106 AND S148

?ss s47 and s108 and s149

*Combine the separate concepts (modern
control theory, flight control, and flexible
aircraft) for those citations in which the
search terms were minor descriptors*

12827 S47
161600 S108
49829 S149
S154 1135 S47 AND S108 AND S149

?ss s45 and s105 and s147

*Combine the separate concepts (modern
control theory, flight control, and flexible
aircraft) for those citations in which the
search terms were in natural language*

14284 S45
201581 S105
58305 S147
S155 1819 S45 AND S105 AND S147

?ss ud=09001:9212b2

Set the update for 1990-1992

S156 205080 UD=9001:9212B2

?ss s153 and s156

*Restrict the citations with major descriptors
by update*

201 S153
205080 S156
S157 71 S153 AND S156

?ss s154 and s156

*Restrict the citations with major or minor descriptors
by update*

1135 S154
205080 S156
S158 357 S154 AND S156

?ss s155 and s156

*Restrict the citations with natural language
by update*

1819 S155
205080 S156
S159 498 S155 AND S156

?ss s158 not s157

*Compared sets by NOTing to compare
citations pulled in through major descriptors,
minor descriptors, and natural language*

357 S158
71 S157
S160 286 S158 NOT S157

?ss s159 not (s157 or s160)

498 S159
71 S157
286 S160
S161 141 S159 NOT (S157 OR S160)

?logoff

Subject Three

DIALOG Recall Search Statement:
File 108:AEROSPACE 62-93/9306B2

Set Items Description

--- ----

?ss computation?()grid?

The computational gridding concept

S1 79544 COMPUTATION?

S2 21657 GRID?

S3 8475 COMPUTATION?()GRID?

?ss adapt?()grid?

S4 33301 ADAPT?

S5 21657 GRID?

S6 470 ADAPT?()GRID?

?ss mesh()redistrib?

S7 6208 MESH

S8 3424 REDISTRIB?

S9 2 MESH()REDISTRIB?

?ss structur?()grid?

S10 281815 STRUCTUR?

S11 21657 GRID?

S12 154 STRUCTUR?()GRID?

?ss grid?()generat?

S13 21657 GRID?

S14 121348 GENERAT?

S15 2688 GRID?()GENERAT?

?ss computat?()fluid?()dynamic?

S16 79574 COMPUTAT?

S17 95669 FLUID?

S18 167348 DYNAMIC?

S19 25040 COMPUTAT?()FLUID?()DYNAMIC?

?ss adapt?()control?

S20 33301 ADAPT?

S21 235043 CONTROL?

S22 8383 ADAPT?()CONTROL?

?ss flow()distrib?

S23 235042 FLOW

S24 272625 DISTRIB?

S25 22463 FLOW()DISTRIB?

?ss s3 or s6 or s9 or s12 or s15 or s19 or s22 or s25

*Combine similar terms for the computational
gridding concept*

8475 S3

470 S6

2 S9

154 S12

2688 S15

25040 S19

8383 S22

22463 S25

S26 56686 S3 OR S6 OR S9 OR S12 OR S15 OR S19 OR S22 OR S25

?ss finite()differen?()theor?

*The finite difference and math theory
concept*

S27 76274 FINITE

S28 230475 DIFFEREN?

S29 304131 THEOR?

S30 15945 FINITE()DIFFEREN?()THEOR?

?ss truncat?()error?

S31 4976 TRUNCAT?

S32 83056 ERROR?

S33 1658 TRUNCAT?()ERROR?

?ss numeric?()analy?

S34 130784 NUMERIC?

S35 546777 ANALY?

S36 31774 NUMERIC?()ANALY?

?ss math?()model?

S37 166198 MATH?

S38 333985 MODEL?

S39 87417 MATH?()MODEL?

?ss coordinate? ?

S40 33623 COORDINATE? ?

?ss coordinat?

S41 37270 COORDINAT?

?ss problem?()solv?

S42 218104 PROBLEM?

S43 391479 SOL?

S44 10792 PROBLEM?()SOL?

?ss precision?

S45 13757 PRECISION?

?ss approximat?

S46 106466 APPROXIMAT?

?ss finite()element?()method?

S47 76274 FINITE

S48 117011 ELEMENT?

S49 350376 METHOD?

S50 29009 FINITE()ELEMENT?()METHOD?

?ss s30 or s33 or s36 or s39 or s41 or s44 or s45 or s46 or s50

*Combine synonyms for the finite difference
and math theory concept*

15945 S30

1658 S33

31774 S36

87417 S39

37270 S41

10792 S44

13757 S45

106466 S46

29009 S50

S51 289158 S30 OR S33 OR S36 OR S39 OR S41 OR S44 OR S45 OR
S46 OR S50

?ss s26 and s51

Combine the two main concepts

56686 S26

289158 S51

S52 20390 S26 AND S51

?ss ud=9001:9212b2

Set the update for 1900-1992

S53 205080 UD=9001:9212B2

?ss s52 and s53

Limit the final set by the update

20390 S52

205080 S53

S54 4447 S52 AND S53

?ss s54/de*

*Sift through the final set to see how many
citations were pulled from major descriptors*

S57 3679 S54/DE*

?ss s54/de

*Sift through the final set to see how many
citations were pulled from major or minor descriptors*

S58 4433 S54/DE

?ss s54 not s58

*Number of records in the set retrieved with
only title and abstract words, i.e. not descriptors.
See also set 68.*

4447 S54
4433 S58
S59 14 S54 NOT S58

?ss s59 not s57
14 S59
3679 S57
S60 14 S59 NOT S57

?ss s54 not (s41 or s44 or s45 or s46)

*Remove terms that seem irrelevant to the
query and caused major jumps in retrieval*

4447 S54
37270 S41
10792 S44
13757 S45
106466 S46
S61 2549 S54 NOT (S41 OR S44 OR S45 OR S46)

?ss s61 not (s19 or s25)
2549 S61
25040 S19
22463 S25
S62 805 S61 NOT (S19 OR S25)

?ss s61/de*

S63 2146 S61/DE*

?ss s61/de

S64 2546 S61/DE

?ss s62/de*

*Sift through the final set to see how many
citations were pulled from major descriptors*

S65 643 S62/DE*

?ss s62/de

*Sift through the final set to see how many
citations were pulled from major or minor descriptors*

S66 803 S62/DE

?ss s66 not s65

803 S66

Number of records pulled from minor descriptors only

643 S65

S67 160 S66 NOT S65

?ss s62 not (s65 or s66)

805 S62

*Number of records retrieved with
only title and abstract words, i.e. not descriptors*

643 S65

803 S66

S68 2 S62 NOT (S65 OR S66)

?ss logoff

Subject Four

DIALOG Recall Search Statement:

File 108:AEROSPACE 62-93/9306B2

Set	Items	Description
-----	-------	-------------

---	-----	-----
-----	-------	-------

?ss unstead?

Search the unsteady/turbulent concept

S1	20243	UNSTEAD?
----	-------	----------

?ss unstead?()state?

S2	20243	UNSTEAD?
----	-------	----------

S3	153467	STATE?
----	--------	--------

S4	1478	UNSTEAD?()STATE?
----	------	------------------

?ss computat?()fluid?()dynamic?

S5	79574	COMPUTAT?
----	-------	-----------

S6	95669	FLUID?
----	-------	--------

S7	167348	DYNAMIC?
----	--------	----------

S8	25040	COMPUTAT?()FLUID?()DYNAMIC?
----	-------	-----------------------------

?ss turbulen?()flow?

S9	70384	TURBULEN?
----	-------	-----------

S10	246544	FLOW?
-----	--------	-------

S11	21177	TURBULEN?()FLOW?
-----	-------	------------------

?ss unstead?()flow?

S12	20243	UNSTEAD?
-----	-------	----------

S13	246544	FLOW?
-----	--------	-------

S14	10785	UNSTEAD?()FLOW?
-----	-------	-----------------

?ss unstead?()aerodynamic?

S15	20243	UNSTEAD?
-----	-------	----------

S16	57908	AERODYNAMIC?
-----	-------	--------------

S17	2784	UNSTEAD?()AERODYNAMIC?
-----	------	------------------------

?ss turbulen?()wake?

S18	70384	TURBULEN?
-----	-------	-----------

S19	12792	WAKE?
-----	-------	-------

S20	2451	TURBULEN?()WAKE?
-----	------	------------------

?ss turbulen?()model?

S21	70384	TURBULEN?
-----	-------	-----------

S22	333985	MODEL?
-----	--------	--------

S23	4584	TURBULEN?()MODEL?
-----	------	-------------------

?ss turbulen?

S24 70384 TURBULEN?

?ss pressur?

S25 149936 PRESSUR?

?ss unstead?()pressur?

S26 20243 UNSTEAD?

S27 149936 PRESSUR?

S28 734 UNSTEAD?()PRESSUR?

?ss turbulen?()effect?

S29 70384 TURBULEN?

S30 454543 EFFECT?

S31 4812 TURBULEN?()EFFECT?

?ss nonstation?()turbulen?

S32 4751 NONSTATION?

S33 70384 TURBULEN?

S34 29 NONSTATION?()TURBULEN?

?ss nonstation?

S35 4751 NONSTATION?

?ss turbulen?()boundar?()layer?

S36 70384 TURBULEN?

S37 135404 BOUNDAR?

S38 121533 LAYER?

S39 11472 TURBULEN?()BOUNDAR?()LAYER?

?ss s1 or s4 or s8 or s11 or s14 or s17 or s20 or s23 or s24 or
s25 or s28

*Combine terms for the unsteady/turbulent
concept*

20243 S1

1478 S4

25040 S8

21177 S11

10785 S14

2784 S17

2451 S20

4584 S23

70384 S24

149936 S25

734 S28

S40 232016 S1 OR S4 OR S8 OR S11 OR S14 OR S17 OR S20 OR
S23 OR S24 OR S25 OR S28

?ss s40 or s31 or s34 or s35 or s39

232016 S40

4812 S31
29 S34
4751 S35
11472 S39
S41 235453 S40 OR S31 OR S34 OR S35 OR S39

?ss incompressib?

Search the incompressible concept

S42 18388 INCOMPRESSIB?

?ss compressib?()effect?

S43 15458 COMPRESSIB?

S44 454543 EFFECT?

S45 1437 COMPRESSIB?()EFFECT?

?ss incompressib?()effect?

S46 18388 INCOMPRESSIB?

S47 454543 EFFECT?

S48 3 INCOMPRESSIB?()EFFECT?

?ss incompressib?()flow?

S49 18388 INCOMPRESSIB?

S50 246544 FLOW?

S51 9317 INCOMPRESSIB?()FLOW?

?ss high()reynold?()number?

S52 288546 HIGH

S53 27196 REYNOLD?

S54 138099 NUMBER?

S55 3039 HIGH()REYNOLD?()NUMBER?

?ss incompressib?()boundar?()layer?

S56 18388 INCOMPRESSIB?

S57 135404 BOUNDAR?

S58 121533 LAYER?

S59 748 INCOMPRESSIB?()BOUNDAR?()LAYER?

?ss incompressib?()fluid?

S60 18388 INCOMPRESSIB?

S61 95669 FLUID?

S62 5832 INCOMPRESSIB?()FLUID?

?ss s42 or s45 or s48 or s51 or s55 or s59 or s62

Combine synonyms for the incompressible concept

18388 S42

1437 S45

3 S48

9317 S51

3039 S55
 748 S59
 5832 S62
 S63 22118 S42 OR S45 OR S48 OR S51 OR S55 OR S59 OR S62

?ss bluff()bod?

Search the bluff bodies concept

S64 1148 BLUFF
 S65 93453 BOD?
 S66 1039 BLUFF()BOD?

?e nonli

Expanding on the term nonlifting in the basic index

Ref	Items	Index-term
E1	1	NONLEVELING
E2	1	NONLEVITATED
E3	1	*NONLI
E4	1	NONLIDAR
E5	1	NONLIEAR
E6	1	NONLIENAR
E7	1	NONLIFE
E8	2	NONLIFT
E9	244	NONLIFTING
E10	8	NONLIFTING VEHICLE
E11	3	NONLIGHT
E12	1	NONLIGHTLY

?ss nonlift?

S67 246 NONLIFT?

?ss non()lift?

S68 36901 NON
 S69 19086 LIFT?
 S70 59 NON()LIFT?

?ss bluff()bod?()flow?

S71 1148 BLUFF
 S72 93453 BOD?
 S73 246544 FLOW?
 S74 36 BLUFF()BOD?()FLOW?

?ss ground?()effect?

S75 70051 GROUND?
 S76 454543 EFFECT?
 S77 3156 GROUND?()EFFECT?

?ss s66 or s67 or s70 or s74 or s77

1039 S66
 246 S67
 59 S70
 36 S74
 3156 S77
 S78 4486 S66 OR S67 OR S70 OR S74 OR S77

Combine synonyms for the bluff body/ground effect concept

?ss s41 and s63 and s78

Combine the three concepts

235453 S41
 22118 S63
 4486 S78
 S79 165 S41 AND S63 AND S78

?ss ud=9001:9212b2

Set the update for 1990-1992

S80 205080 UD=9001:9212B2

?ss s79 and s80

Limit by the update

165 S79
 205080 S80
 S81 26 S79 AND S80

Due to small search set, decided to reexamine the relation of the concepts to each other. Current use of ANDing might be inappropriate due to the meaning of the terms and their relation to one another in the indexing language hierarchy.

?ss finite analy()analy?()method?

Unsure of the meaning of these terms and where they fit in the structure of the query so they were excluded (s85 and s89) from final sets

S82 76274 FINITE
 S83 546777 ANALY?
 S84 350376 METHOD?
 S85 32 FINITE()ANALY?()METHOD?

?ss finite()differen?()theor?

S86 76274 FINITE
 S87 230475 DIFFEREN?
 S88 304131 THEOR?
 S89 15945 FINITE()DIFFEREN?()THEOR?

?ss s41 or s63

235453 S41

22118 S63
S90 245019 S41 OR S63

?ss s90 and s78

*Combine the unsteady concept and the bluff
body concept*

245019 S90
4486 S78
S91 1665 S90 AND S78

?ss s90 or (s85 or s89 or (finite())element?)

*Include finite element in the unsteady
concept*

245019 S90
32 S85
15945 S89
S92 76274 FINITE
S93 117011 ELEMENT?
S94 31200 FINITE(W)ELEMENT?
S95 278359 S90 OR S85 OR S89 OR (FINITE())ELEMENT?)

?ss s95 and s78

*Combine the unsteady concept and bluff body
concept*

278359 S95
4486 S78
S96 1697 S95 AND S78

?ss s80 and s96

Limit by the update

205080 S80
1697 S96
S97 241 S80 AND S96

?ss s85 or s89 or s94

*Combine finite difference, finite element and
finite analysis*

32 S85
15945 S89
31200 S94
S98 45673 S85 OR S89 OR S94

?ss s90 and s98 and s78

*Combine the unsteady concept, the finite
difference/element/analysis concept, and the
bluff body concept*

245019 S90
45673 S98
4486 S78

S99 95 S90 AND S98 AND S78

?ss s99 and s80

Limit by the update

95 S99
205080 S80
S100 15 S99 AND S80

?ss s97/de*

Sift for major descriptors

S101 190 S97/DE*

?ss s97/de

Sift for major or minor descriptors

S102 234 S97/DE

?ss s97 not s101

*The NOTed sets are checking for duplicates.
Used set 97 as the final set.*

241 S97
190 S101
S103 51 S97 NOT S101

?ss s101 not s102

190 S101
234 S102
S104 0 S101 NOT S102

?ss s102 not s101

234 S102
190 S101
S105 44 S102 NOT S101

?ss s97 not (s101 or s102)

241 S97
190 S101
234 S102

S106 7 S97 NOT (S101 OR S102)

?logoff

Appendix B. BBS Precision Search Strategies

QUESTION 1

Set Items Description

--- ----

?ss aerodynamic?()stall?/de

S1 51164 AERODYNAMIC?/DE

S2 2527 STALL?/DE

S3 1907 AERODYNAMIC?()STALL?/DE

?ss stall?/de

S4 2527 STALL?/DE

?ss s3 or s4

1907 S3

2527 S4

S5 2527 S3 OR S4

?ss computer()program?de

S6 202425 COMPUTER?

S7 0 PROGRAM?DE

S8 0 COMPUTER?()PROGRAM?DE

?ss computer?/()program?/de

S9 177936 COMPUTER?/DE

S10 125934 PROGRAM?/DE

S11 66375 COMPUTER?()PROGRAM?/DE

?ss math?()model?/de

S12 154874 MATH?/DE

S13 177623 MODEL?/DE

S14 85604 MATH?()MODEL?/DE

?ss s11 or s14

66375 S11

85604 S14

S15 144914 S11 OR S14

?ss turbulen?/de

S16 62291 TURBULEN?/DE

?ss boundar?()layer?/de

S17 102138 BOUNDAR?/DE

S18 66592 LAYER?/DE

S19 46540 BOUNDAR?()LAYER?/DE

?ss unstead?/de

S20 13212 UNSTEAD?/DE

?ss s16 or s19 or s20

62291 S16
46540 S19
13212 S20
S21 101505 S16 OR S19 OR S20

?ss wind?/de
S22 83479 WIND?/DE

?ss turbine?/de
S23 26313 TURBINE?/DE

?ss rotor?/de
S24 14745 ROTOR?/DE

?ss s22 or s23 or s24
83479 S22
26313 S23
14745 S24
S25 117748 S22 OR S23 OR S24

?c 5 and 15 and 21 and 25
2527 5
144914 15
101505 21
117748 25
S26 24 5 AND 15 AND 21 AND 25

?ss ud=9001:9212b2
S27 205080 UD=9001:9212B2

?c 26 and 27
24 26
205080 27
S28 3 26 AND 27

?ss s21 or flow?
101505 S21
S29 251436 FLOW?
S30 282542 S21 OR FLOW?

?ss s21 or flow?/de
101505 S21
S31 205276 FLOW?/DE
S32 239863 S21 OR FLOW?/DE

?c 5 and 15 and 32 and 25
2527 5
144914 15
239863 32

117748 25
S33 52 5 AND 15 AND 32 AND 25

?c 27 and 33
205080 27
52 33
S34 8 27 AND 33

?ss s25 or wind?/ti
117748 S25
S35 32419 WIND?/TI
S36 119527 S25 OR WIND?/TI

?ss s32 or (turbulen?/ti or unstead?/ti)
239863 S32
S37 33702 TURBULEN?/TI
S38 8260 UNSTEAD?/TI
S39 241305 S32 OR TURBULEN?/TI OR UNSTEAD?/TI

?c 5 and 15 and 39 and 36
2527 5
144914 15
241305 39
119527 36
S40 54 5 AND 15 AND 39 AND 36

?ss s3 or stall?()delay?
1907 S3
S41 4156 STALL?
S42 18433 DELAY?
S43 26 STALL?(W)DELAY?
S44 1913 S3 OR STALL?()DELAY?

?c 44 and 15 and 39 and 36
1913 44
144914 15
241305 39
119527 36
S45 42 44 AND 15 AND 39 AND 36

?c 27 and 45
205080 27
42 45
S46 6 27 AND 45

?ss aerodynamic?/de* or stall?/de
S47 31838 AERODYNAMIC?/DE*
S48 2527 STALL?/DE
S49 32857 AERODYNAMIC?/DE* OR STALL?/DE

?c 49 or 15 or 39 or 36
32857 49
144914 15
241305 39
119527 36
S50 444822 49 OR 15 OR 39 OR 36

?ss s5 or stall?()delay?
2527 S5
S51 4156 STALL?
S52 18433 DELAY?
S53 26 STALL?(W)DELAY?
S54 2531 S5 OR STALL?()DELAY?

?c 54 and 15 and 39 and 36
2531 54
144914 15
241305 39
119527 36
S55 54 54 AND 15 AND 39 AND 36

?c 27 and 55
205080 27
54 55
S56 8 27 AND 55

QUESTION 2

Set Items Description

--- -----

?ss ud=9001:9212b2

S1 205080 UD=9001:9212B2

?ss modern()control()theor?

S2 9259 MODERN

S3 206837 CONTROL

S4 306568 THEOR?

S5 239 MODERN()CONTROL()THEOR?

?ss h()2

S6 40803 H

S7 197069 2

S8 449 H()2

?ss h()infini?

S9 40803 H

S10 23500 INFINIT?

S11 653 H()INFINIT?

?ss s5 or s8 or s11

239 S5

449 S8

653 S11

S12 1325 S5 OR S8 OR S11

?ss robustness

S13 5387 ROBUSTNESS

?ss robust?(3w)control

S14 8098 ROBUST?

S15 206837 CONTROL

S16 1112 ROBUST?(3W)CONTROL

?ss flight()control()system?

S17 107537 FLIGHT

S18 206837 CONTROL

S19 513422 SYSTEM?

S20 2912 FLIGHT()CONTROL()SYSTEM?

?ss multivariable control

S21 169 MULTIVARIABLE CONTROL

?ss (control()synthesis)/ti

S22 61577 CONTROL/TI

S23 10881 SYNTHESIS/TI
S24 212 (CONTROL()SYNTHESIS)/TI

?ss (feedback control)/de*
S25 8826 (FEEDBACK CONTROL)/DE*

?ss feedback control
S26 15751 FEEDBACK CONTROL

?ss multivariable()feedback()control()system
S27 3069 MULTIVARIABLE
S28 26930 FEEDBACK
S29 206837 CONTROL
S30 340935 SYSTEM
S31 12 MULTIVARIABLE()FEEDBACK()CONTROL()SYSTEM

?ss active()modal()suppression()system
S32 34732 ACTIVE
S33 9402 MODAL
S34 6541 SUPPRESSION
S35 340935 SYSTEM
S36 1 ACTIVE()MODAL()SUPPRESSION()SYSTEM

?ss s20 or s13 or s21 or s16 or s24
2912 S20
5387 S13
169 S21
1112 S16
212 S24
S37 8648 S20 OR S13 OR S21 OR S16 OR S24

?ss s37 or s31 or s36
8648 S37
12 S31
1 S36
S38 8657 S37 OR S31 OR S36

?ss transport aircraft
S39 4754 TRANSPORT AIRCRAFT

?e flexible aircraft
Ref Items Index-term
E1 2 FLEXIBILITY
E2 14693 FLEXIBLE
E3 0 *FLEXIBLE AIRCRAFT
E4 3318 FLEXIBLE BODIES
E5 98 FLEXIBLE BODY
E6 1777 FLEXIBLE SPACECRAFT
E7 45 FLEXIBLE WING

E8 297 FLEXIBLE WINGS
E9 27 FLEXIBLEN
E10 4 FLEXIBLER
E11 20 FLEXIBLES
E12 2 FLEXIBILITY

?ss (flexible()bod? or wing?)/de

S40 5622 FLEXIBLE/DE
S41 61501 BOD?/DE
S42 3416 FLEXIBLE/DE(W)BOD?/DE
S43 25162 WING?/DE
S44 28500 (FLEXIBLE()BOD? OR WING?)/DE

?ss (flexible()(bod? or wing?))/de

S45 5622 FLEXIBLE/DE
S46 61501 BOD?/DE
S47 25162 WING?/DE
S48 3754 (FLEXIBLE()(BOD? OR WING?))/DE

?ss x()29

S49 95226 X
S50 6525 29
S51 296 X()29

?ss lynx()helicopter?

S52 146 LYNX
S53 16531 HELICOPTER?
S54 67 LYNX()HELICOPTER?

?ss maneuverable()aircraft()design?

S55 692 MANEUVERABLE
S56 121850 AIRCRAFT
S57 263297 DESIGN?
S58 2 MANEUVERABLE()AIRCRAFT()DESIGN?

?ss s39 or s48 or s51 or s54 or s58

4754 S39
3754 S48
296 S51
67 S54
2 S58
S59 8853 S39 OR S48 OR S51 OR S54 OR S58

?c 12 and 38 and 59

1325 12
8657 38
8853 59
S60 31 12 AND 38 AND 59

?c 60 and 1

31 60

205080 1

S61 25 60 AND 1

?ss s12 or (control()theory)/de*

1325 S12

S62 105897 CONTROL/DE*

S63 68393 THEORY/DE*

S64 7289 CONTROL/DE*(W)THEORY/DE*

S65 8339 S12 OR (CONTROL()THEORY)/DE*

?c 65 and 38 and 59

8339 65

8657 38

8853 59

S66 65 65 AND 38 AND 59

?c 1 and 66

205080 1

65 66

S67 42 1 AND 66

?ss s67 not s61

42 S67

25 S61

S68 17 S67 NOT S61

QUESTION 3

Set Items Description

--- -----

?ss grid?()generat?/de*

S1 4795 GRID?/DE*

S2 22734 GENERAT?/DE*

S3 1243 GRID?()GENERAT?/DE*

?ss finit?()different?()theor?/de

S4 47451 FINIT?/DE

S5 67381 DIFFEREN?/DE

S6 154251 THEOR?/DE

S7 16218 FINIT?()DIFFEREN?()THEOR?/DE

?ss finit?()element?()method?/de

S8 47451 FINIT?/DE

S9 54517 ELEMENT?/DE

S10 105570 METHOD?/DE

S11 29106 FINIT?()ELEMENT?()METHOD?/DE

?ss s7 or s11

16218 S7

29106 S11

S12 43955 S7 OR S11

?ss s3 and s12

1243 S3

43955 S12

S13 360 S3 AND S12

?ss ud=9001:9212b2

S14 205080 UD=9001:9212B2

?ss s14 and s13

205080 S14

360 S13

S15 236 S14 AND S13

?ss s7/de*

S16 6363 S7/DE*

?ss s11/de*

S17 16425 S11/DE*

?ss s16 or s17

6363 S16

16425 S17

S18 22413 S16 OR S17

?ss s3 and s16
6363 S16
1243 S3
S20 52 S3 AND S16

?ss s14 and s20
205080 S14
52 S20
S21 37 S20 AND S14

?ss s21 not computat?()fluid?()dynamic?
37 S21
S22 82336 COMPUTAT?
S23 97938 FLUID?
S24 171698 DYNAMIC?
S25 26184 COMPUTAT?(W)FLUID?(W)DYNAMIC?
S26 23 S21 NOT COMPUTAT?()FLUID?()DYNAMIC?

QUESTION 4

?ss flow? or wake? or turbulen? or stabilit?

S2 248235 FLOW?

S3 12907 WAKE?

S4 70918 TURBULEN?

S5 136185 STABILI?

S6 383912 FLOW? OR WAKE? OR TURBULEN? OR STABILI?

?ss s6/ti

S7 146622 S6/TI

?ss bluff()bod?/ti

S8 453 BLUFF/TI

S9 24657 BOD?/TI

S10 387 BLUFF()BOD?/TI

?ss s7 and s10

146622 S7

387 S10

S11 286 S7 AND S10

?ss ud=9001:9212b2

S13 205080 UD=9001:9212B2

?ss s11 and s13

286 S11

205080 S13

S14 38 S11 AND S13

?ss computat? or computational () fluid ()
dynamic? or reynold's () number

S15 80575 COMPUTAT?

S16 52140 COMPUTATIONAL

S17 81766 FLUID

S18 169087 DYNAMIC?

S19 25391 COMPUTATIONAL(W)FLUID(W)DYNAMIC?

S20 0 REYNOLD'S

S21 127151 NUMBER

S22 0 REYNOLD'S(W)NUMBER

S23 80575 COMPUTAT? OR COMPUTATIONAL()FLUID()DYNAMIC? OR
REYNOLD'S()NUMBER

? e reynold

E1 1 REYNODS

E2 4 REYNOL

E3 174 *REYNOLD

E4 27314 REYNOLDS

E5 786 REYNOLDS EQUATION

E6 15690 REYNOLDS NUMBER

E7 75 REYNOLDS NUMBER EFFECT

E8 2540 REYNOLDS STRESS
E9 2 REYNOLDSA
E10 1 REYNOLDSD
E11 2 REYNOLDSOVA
E12 1 REYNOLDSOVO

?ss e4,e7

S24 27314 REYNOLDS
S25 75 REYNOLDS NUMBER EFFECT
S26 27314 E4,E7

?ss s15 or (s15 or s19 or s26)/ti

S27 12189 S15/TI
S28 529 S19/TI
S29 3926 S26/TI
S30 16054 (S15 OR S19 OR S26)/TI

?ss s30 and s13

16054 S30
205080 S13
S31 2449 S30 AND S13

?ss s7 and s31

146622 S7
2449 S31
S32 824 S7 AND S31

?ss s32 and s13

824 S32
205080 S13
S33 824 S32 AND S13

Appendix C. WAIS Search Strategies

WAIS Terse Strategies

QUESTION 1

unsteady aerodynamics stall delay model air flows propeller

QUESTION 2

flight control system modern control theory flexible aircraft

QUESTION 3

adaptive gridding grid generation mesh redistribution truncation error structured flow mechanics

QUESTION 4

computational fluid dynamics bluff body

WAIS Verbose Strategies

QUESTION 1

unsteady state flow aerodynamics pressure turbulence flow wake model effects boundary layers
mathematical models computer models digital simulation high solidity propellers compressed rotor
stator blades wind power generator

QUESTION 2

modern control theory flight control design flight control active control h-infinity h-2 control system
design flexible aircraft body model dynamic model transport aircraft control configured vehicle"

QUESTION 3

grid adaptive gridding mesh redistribution structural gridding grid generation computational fluid
dynamics adaptive control flow distribution finite difference theory truncation error numeric analysis
numerical analysis mathematical models math model mathematical model coordinate coordinates
coordination coordinating problem solving approximate approximation approximating finite elemental
method finite element method

QUESTION 4

unsteady state computational fluid dynamics turbulence flow turbulent flow unsteady flow unsteady
aerodynamics turbulent wake turbulent wakes turbulent model turbulence pressure unsteady pressure
turbulence effect nonstationary pressure nonstationary turbulence turbulence boundary layer
incompressible compressible effect incompressible flow high reynolds number incompressible
boundary layer incompressible fluid bluff bodies nonlifting non-lifting bluff body flow ground effect
finite analysis method finite difference theory

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